# TRANSACTIONS

## The American Fisheries Society

1938

SIXTY-EIGHTH ANNUAL MEETING
ASHEVILLE, NORTH CAROLINA
JUNE 23 and 24, 1938

# Transactions

of the

# American Fisheries Society

SIXTY-EIGHTH ANNUAL MEETING

Asheville, North Carolina

JUNE 23 and 24, 1938

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# THE AMERICAN FISHERIES SOCIETY

**Organized 1870** **Incorporated 1910**

The Society was organized to promote the cause of fish culture; to gather and diffuse information of a scientific character; and to unite and encourage those interested in fish culture and fisheries problems.

## OFFICERS FOR 1937-1938

*President* ........ I. T. QUINN, Montgomery, Alabama
*First Vice-President* ........ FRED J. FOSTER, Seattle, Wash.
*Second Vice-President* ........ T. H. LANGLOIS, Put-in-Bay, Ohio
*Secretary-Treasurer* ........ SETH GORDON, Harrisburg, Pa.
Address all routine mail to the Secretary, Investment Bldg., Washington, D. C.
*Librarian* ........ KENNETH E. COBB, Windsor Locks, Conn.

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*Commercial Fishing* ........ LESTER SMITH, Port Washington, Wis.
*Protection and Legislation* ........ B. M. BRENNAN, Seattle, Wash.
*Angling* ........ JAMES BROWN, Frankfort, Ky.

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### VICE-PRESIDENTS OF DIVISIONS

*Fish Culture* ........ H. H. MACKAY, Toronto, Canada
*Aquatic Biology and Physics* ........ L. R. DONALDSON, Seattle, Wash.
*Commercial Fishing* ........ H. J. DEASON, Ann Arbor, Mich.
*Protection and Legislation* ........ WILLIAM C. ADAMS, Albany, N. Y.
*Angling* ........ C. R. GUTERMUTH, Indianapolis, Ind.

*For street address see membership list.

## STANDING COMMITTEES, 1938-1939

### Executive Committee

The Executive Committee consists of the president, vice-presidents, secretary, librarian, vice-presidents of divisions, and I. T. Quinn, the president last year.

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| Charles E. Jackson, *Chairman* | Washington, D. C. |
| B. M. Brennan | Seattle, Wash. |
| Russell P. Hunter | Hartford, Conn. |
| James A. Rodd | Ottawa, Canada |
| William J. Tucker | Austin, Texas |
| John Van Oosten | Ann Arbor, Mich. |
| Senor Juan Zinser | Mexico City, Mex. |

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| | |
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| Samuel F. Hildebrand | Washington, D. C. |
| Carl L. Hubbs | Ann Arbor, Mich. |
| A. H. Leim | St. Andrews, N. B., Canada |
| George S. Myers | Stanford University, Calif. |
| Leonard P. Schultz | Washington, D. C. |

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---

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| | |
|---|---|
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| A. S. Hazzard | Ann Arbor, Mich. |
| Carl L. Hubbs | Ann Arbor, Mich |
| A. G. Huntsman | Toronto, Canada |
| S. B. Locke | Boston, Mass. |
| James A. Rodd | Ottawa, Canada |
| Clarence M. Tarzwell | Decatur, Ala. |
| John Van Oosten | Ann Arbor, Mich. |
| Geo. C. Warren, Jr. | Summit, N. J. |

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| Henry B. Ward | Urbana, Ill. |

## PRESIDENTS' TERMS OF SERVICE AND PLACES OF MEETING

The first meeting of the Society occurred December 20, 1870. The organization then effected continued until February, 1872, when the second meeting was held Since that time there has been a meeting each year, as shown below. The respective presidents were elected at the meeting, at the place, and for a period shown opposite their names, but they presided at the subsequent meeting.

| | | |
|---|---|---|
| 1. William Clift | 1870-1872 | New York, N. Y. |
| 2. William Clift | 1872-1873 | Albany, N. Y. |
| 3. William Clift | 1873-1874 | New York, N. Y. |
| 4. Robert B. Roosevelt | 1874-1875 | New York, N. Y. |
| 5. Robert B. Roosevelt | 1875-1876 | New York, N. Y. |
| 6. Robert B. Roosevelt | 1876-1877* | New York, N. Y. |
| 7. Robert B. Roosevelt | 1877-1878 | New York, N. Y. |
| 8. Robert B. Roosevelt | 1878-1879 | New York, N. Y. |
| 9. Robert B. Roosevelt | 1879-1880 | New York, N. Y. |
| 10. Robert B. Roosevelt | 1880-1881 | New York, N. Y. |
| 11. Robert B. Roosevelt | 1881-1882 | New York, N. Y. |
| 12. George Shepard Page | 1882-1883 | New York, N. Y. |
| 13. James Benkard | 1883-1884 | New York, N. Y. |
| 14. Theodore Lyman | 1884-1885 | Washington, D. C. |
| 15. Marshall McDonald | 1885-1886 | Washington, D. C. |
| 16. W. M. Hudson | 1886-1887 | Chicago, Ill. |
| 17. William L. May | 1887-1888 | Washington, D. C. |
| 18. John Bissell | 1888-1889 | Detroit, Mich. |
| 19. Eugene G. Blackford | 1889-1890 | Philadelphia, Pa. |
| 20. Eugene G. Blackford | 1890-1891 | Put-in-Bay, Ohio |
| 21. James A. Henshall | 1891-1892 | Washington, D. C. |
| 22. Herschel Whitaker | 1892-1893 | New York, N. Y. |
| 23. Henry C. Ford | 1893-1894 | Chicago, Ill. |
| 24. William L. May | 1894-1895 | Philadelphia, Pa. |
| 25. L. D. Huntington | 1895-1896 | New York, N. Y. |
| 26. Herschel Whitaker | 1896-1897 | New York, N. Y. |
| 27. William L. May | 1897-1898 | Detroit, Mich. |
| 28. George F. Peabody | 1898-1899 | Omaha, Nebr. |
| 29. John W. Titcomb | 1899-1900 | Niagara Falls, N. Y. |
| 30. F. B. Dickerson | 1900-1901 | Woods Hole, Mass. |
| 31. E. E. Bryant | 1901-1902 | Milwaukee, Wis. |
| 32. George M. Bowers | 1902-1903 | Put-in-Bay, Ohio |
| 33. Frank N. Clark | 1903-1904 | Woods Hole, Mass. |
| 34. Henry T. Root | 1904-1905 | Atlantic City, N. J. |
| 35. C. D. Joslyn | 1905-1906 | White Sulphur Springs, W. Va. |

*A special meeting was held at the Centennial Grounds, Philadelphia, Pa., October 6 and 7, 1876.

| | | |
|---|---|---|
| 36. E. A. Birge | 1906-1907 | Grand Rapids, Mich. |
| 37. Hugh M. Smith | 1907-1908 | Erie, Pa. |
| 38. Tarleton H. Bean | 1908-1909 | Washington, D. C. |
| 39. Seymour Bower | 1909-1910 | Toledo, Ohio |
| 40. William E. Meehan | 1910-1911 | New York, N. Y. |
| 41. S. F. Fullerton | 1911-1912 | St. Louis, Mo. |
| 42. Charles H. Townsend | 1912-1913 | Denver, Colo. |
| 43. Henry B. Ward | 1913-1914 | Boston, Mass. |
| 44. Daniel B. Fearing | 1914-1915 | Washington, D. C. |
| 45. Jacob Reighard | 1915-1916 | San Francisco, Calif. |
| 46. George W. Field | 1916-1917 | New Orleans, La. |
| 47. Henry O'Malley | 1917-1918 | St. Paul, Minn. |
| 48. M. L. Alexander | 1918-1919 | New York, N. Y. |
| 49. Carlos Avery | 1919-1920 | Louisville, Ky. |
| 50. Nathan R. Buller | 1920-1921 | Ottawa, Canada |
| 51. William E. Barber | 1921-1922 | Allentown, Pa. |
| 52. Glen C. Leach | 1922-1923 | Madison, Wis. |
| 53. George C. Embody | 1923-1924 | St. Louis, Mo. |
| 54. Eben W. Cobb | 1924-1925 | Quebec, Canada |
| 55. Charles O. Hayford | 1925-1926 | Denver, Colo. |
| 56. John W. Titcomb | 1926-1927 | Mobile, Ala. |
| 57. Emmeline Moore | 1927-1928 | Hartford, Conn. |
| 58. C. F. Culler | 1928-1929 | Seattle, Wash. |
| 59. David L. Belding | 1929-1930 | Minneapolis, Minn. |
| 60. E. Lee LeCompte | 1930-1931 | Toronto, Canada |
| 61. James A. Rodd | 1931-1932 | Hot Springs, Arkansas |
| 62. H. S. Davis | 1932-1933 | Baltimore, Md. |
| 63. Fred A. Westerman | 1933-1934 | Columbus, Ohio |
| 64. E. L. Wickliff | 1934-1935 | Montreal, Canada |
| 65. Frank T. Bell | 1935-1936 | Tulsa, Okla. |
| 66. A. G. Huntsman | 1936-1937 | Grand Rapids, Mich. |
| 67. I. T. Quinn | 1937-1938 | Mexico City, Mexico |
| 68. Fred J. Foster | 1938-1939 | Asheville, N. C. |

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# BUSINESS SESSIONS

# TRANSACTIONS

## of the 68th Annual Meeting of the AMERICAN FISHERIES SOCIETY

### ASHEVILLE, NORTH CAROLINA

### JUNE 23 AND 24, 1938

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The 68th Annual Meeting of the American Fisheries Society convened at 9:00 a.m., June 23, 1938, at the Battery Park Hotel, Asheville, North Carolina, the President, Hon. I. T. Quinn, of Montgomery, Alabama, presiding.

The meetings were held in cooperation with the 32nd Annual Convention of the International Association of Game, Fish and Conservation Commissioners.

The registered attendance of members, delegates, and guests was as follows:

#### REGISTERED MEMBERS IN ATTENDANCE

Adams, William C., Albany, N. Y.
Aldrich, A. D., Tulsa, Okla.
Atwood, E. L., St. Louis, Mo.
Aylward, David A., Cambridge, Mass. (Rep. Mass. Fish and Game Assn.)

Baker, C. L., Memphis, Tenn.
Bangham, Ralph V., Wooster, Ohio
Barker, Elliott S., Santa Fe, New Mex.
Bell, Frank T., Washington, D. C.
Bost, J. E., Greer, S. C.
Breder, C. M., New York, N. Y.
Brennan, B. M., Seattle, Wash.
Bronson, E. P., Hartford, Conn.
Brown, James, Frankfort, Ky.
Buntin, Howell, Nashville, Tenn. (Rep. Tenn. Cons. Dept.)

Chalk, J. D., Raleigh, N. C.
Chute, W. H., Chicago, Ill.
Clark, Arthur L., Jefferson City, Mo.
Cobb, Kenneth E., Windsor Locks, Conn.
Cook, A. B., Ionia, Mich.
Corcoran, J. P., Centerville, Md.
Culler, C. F., La Crosse, Wis.

Davis, Herbert C., San Francisco, Calif. (Rep. Calif. Div. of Fish and Game)
Davis, H. S., Washington, D. C.
Dean, Ernest J., Boston, Mass. (Rep. Mass. Dept. of Game)
Deason, H. J., Ann Arbor, Mich.
Denmead, Talbott, Washington, D. C.
Dent, T. J., Hanover, N. H. (Rep. N. H. Fish and Game Com.)
Duer, Robert F., Baltimore, Md. (Rep. Md. Cons. Com.)

Earle, Swepson, Baltimore, Md.
Ellis, M. M., Columbia, Mo.
Ethridge, R. Bruce, Raleigh, N. C. (Rep. N. C. Dept. of Cons. and Development)

Fearnow, Theodore C., Berkeley Springs, W. Va.
Fiedler, R. H., Washington, D. C.
Foster, Charles S., Dover, Del. (Rep. Del. Bd. of Game and Fish Comrs.)
Foster, Fred J., Seattle, Wash.

Gordon, Seth, Harrisburg, Pa.
Gottschalk, John, Indianapolis, Ind.
Graves, N., Little Rock, Ark.
Gutermuth, C. R., Indianapolis, Ind.
Gutsell, J. S., Kearneysville, Va.

Hart, M. D., Richmond, Va. (Rep. Va. Com. of Game and Inland Fisheries)
Hayford, Chas. O., Hackettstown, N. J.
Hazzard, A. S., Ann Arbor, Mich.
Herndon, G. B., Jefferson City, Mo.
Higgins, Elmer, Washington, D. C.
Hill, Burt J., Columbus, Ohio.
Hoffmaster, P. J., Lansing, Mich.
Holland, R. P., New York, N. Y.
Holloway, Ancil, Atlanta, Ga.
Hudleson, Lee, Lincoln, Neb. (Rep. Neb. Game, Forestation and Parks Com.)
Hunter, R. P., Montpelier, Vt. (Rep. Vt. Game and Fish Service)
Hutton, M. L., Des Moines, Iowa

Jackson, Charles E., Washington, D. C.
James, M. C., Washington, D. C.
Johnson, O. H., Pierre, S. Dak. (Rep. S. Dak. Game and Fish Dept.)

Keil, W. M., Asheville, N. C.
King, Willis, Elkmont, Tenn.
Kitson, J. Arthur, Boston, Mass.

Kuhne, Eugene R., Nashville, Tenn.
Kunkel, Kenneth M., Indianapolis, Ind.

LeCompte, E. Lee, Baltimore, Md.
Leonard, J. W., Ann Arbor, Mich.
Lincoln, Guy, Oden, Mich.
Lindner, M. J., New Orleans, La.
Locke, S. B., Boston, Mass.
Loutit, W. H., Grand Haven, Mich.
Lucas, Clarence L., Washington, D. C.
Lyttle, R. G., Meeker, Colo. (Rep. Colo. Game and Fish Com.)

MacKay, H. H., Toronto, Canada
Madsen, David H., Salt Lake City, Utah
Markus, Henry C., Rochester, N. Y.
Meehean, O. Lloyd, Welaka, Fla.

O'Connell, Frank B., Lincoln, Neb. (Rep. Neb. Game and Fish Com.)

Powell, Albert, Baltimore, Md.
Prevost, Gustave, Montreal, Canada

Quinn, I. T., Montgomery, Ala.

Scott, John W., Cheyenne, Wyo.
Shawhan, H. W., Charleston, W. Va. (Rep. W. Va. Conservation Com.)
Shetter, D. S., Ann Arbor, Mich.

Shoemaker, Carl D., Washington, D. C.
Smith, E. V., Auburn, Ala.
Snipes, Frank L., Flintville, Tenn.
Speakes, H. E., St. Paul, Minn. (Rep Minn. Div. of Game and Fish)
Surber, Eugene, Kearneysville, W. Va.
Swingle, H. S., Auburn, Ala.

Truitt, R. V., Solomons Island, Md.
Tucker, William J., Austin, Tex.

Vaill, C. B. H., Hartford, Conn.
Van Oosten, John, Ann Arbor, Mich.

Wallace, David H., Solomons Island, Md.
Wascke, Harold L., Columbus, Ohio
Webb, Larry, Salina, Kan. (Rep. Kan. Forestry, Fish & Game Com.)
Westerman, F. A., Lansing, Mich.
Wickliff, E. L., Columbus, Ohio
Wilkinson, J. T., Lansing, Mich.
Wire, F. B., Portland, Ore. (Rep. Ore. Game Com.)

Zinser, Señor Juan, Mexico City, Mexico

## Registered Visitors in Attendance

Ajgerman, E. K., Morgantown, N. C.
Aldrich, Mrs. A. D., Tulsa, Okla.
Aldrich, Bob, Tulsa, Okla.
Anderson, W. M., Morgantown, N. C.
Atwood, Mrs. E. L., Kirkwood, Mo.

Bartlett, Frank H., Asheville, N. C.
Bowie, Tom, Jr., W. Jefferson, N. C.
Bradshaw, J. A., Asheville, N. C.
Branch, P. H., Asheville, N. C.
Brewster, Sam F., Nashville, Tenn.
Brown, Lester E., Cape Elizabeth, Maine
Bryan, L. F., Conway, S. C.
Buck, Clarence F., Monmouth, Ill.
Buntin, Mrs. Howell, Nashville, Tenn.
Burch, R. F., Atlanta, Ga.
Burnham, Chas. W., Asheville, N. C.

Caldwell, J. R., Prentiss, N. C.
Caldwell, John, Nashville, Tenn.
Callaghan, F. P., Washington, D. C.
Carter, F. Piercy, Asheville, N. C.
Chalk, Mrs. J. D., Raleigh, N. C.
Chisholm, W. F., Shreveport, La.
Chute, Dudley H., Chicago, Ill.
Chute, Mrs. W. H., Chicago, Ill.
Connell, J. T., Springfield, Tenn.
Cooke, Newell B., Salt Lake City, Utah
Crews, F. W., Hickory, N. C.
Crouch, W. E., Washington, D. C.

Davis, C. C., Norris, Tenn.
Day, A. M., Washington, D. C.
DeLaBarre, C. F., Blacksburg, Va.
Denmead, Carolyn, Baltimore, Md.
Denmead, Mrs. Talbott, Baltimore, Md.
Duer, Mrs. Robert F., Baltimore, Md.

Eatman, Frank W., Hoffman, N. C.
Elledge, Mrs. Eva C., Washington, D. C.

Floyd, E. V., Greensboro, N. C.
Frison, T. H., Urbana, Ill.
Fritz, J. J., Middlebury, Vt.
Fritz, Mrs. J. J., Middlebury, Vt.

Gabrielson, Ira N., Washington, D. C.
Gilchrist, Don, Albuquerque, N. Mex.
Gilkey, J. Q., Marion, N. C.
Gordon, Phyllis, Harrisburg, Pa.
Gordon, Mrs. Seth, Harrisburg, Pa.
Graham, John H., Charleston, W. Va.
Gresh, W. A., Charleston, W. Va.

Hammond, J. S., Columbia, S. C.
Harris, O. B., Beckley, W. Va.
Harris, R. S., Ellenbora, W. Va.
Hatton, John H., Washington, D. C.
Haub, J. G., Columbus, Ohio
Hazzard, Mrs. A. S., Ann Arbor, Mich.
Heyward, Zan., Columbia, S. C.
Hoffmaster, Marjory Jean, Lansing, Mich.
Hoffmaster, Mrs. P. J., Lansing, Mich.
Hoffmaster, Robert, Lansing, Mich.
Holland, Mrs. Ray P., New York, N. Y.
Huggins, Mrs. Bill M., Marion, S. C.
Hunt, F. D., Springfield, Ill.
Hunter, Mrs. R. P., Montpelier, Vt.
Huntington, John C., New York, N. Y.
Hutterstrum, D. W., Bismarck, N. Dak.
Hutton, Mrs. M. L., Ames, Iowa.

James, Ben H., Kinston, N. C.
Johnson, Charles M., Raleigh, N. C.

Kennedy, I. N., Tallahassee, Fla.
Kistler, J. W., Rockingham, N. C.

Laythe, Leo L., Denver, Colo.
LeCompte, Mrs. E. Lee, Cambridge, Md.
Leonard, Mrs. J. W., Ann Arbor, Mich.
Lincoln, Frederick, Washington, D. C.
Lincoln, Mrs. Guy, Oden, Mich.
Lindsey, David, Spindale, N. C.
Loutit, Mrs. W. H., Grand Haven, Mich.

Maurek, Burnie W., Omaha, Neb.
McCullough, G. W., Minneapolis, Minn.
McLean, Roger W., Raleigh, N. C.
Meadows, E. L., Raleigh, N. C.
Mease, C. N., Marion, N. C.
Miller, J. P., Washington, D. C.
Morford, Earle H., Charleston, W. Va.

Morford, Pattie, Charleston, N. C.
Morrison, Kathleen, Asheville, N. C.
Murray, T. B., Washington, D. C.

Needham, J. T., Bryson City, N. C.
Nesbitt, R. A., Washington, D. C.
Nolting, C. H., Richmond, Va.

Ochsner, H. E., Asheville, N. C.
Overbay, C. H., Asheville, N. C.

Palmer, C. M., Jr., Washington, D. C.
Palmer, Geo., Lewiston, Md.
Pearson, A. M., Auburn, Ala.
Peck, Mrs. Hal C., Midland, Tex.
Phillips, F. Donald, Rockingham, N. C.
Phipps, Frank, Frankfort, Ky.
Plott, G. C., Waynesville, N. C.
Powell, Alton, Baltimore, Md.

Quee, Ethel M., Washington, D. C.
Quee, Mrs. Ida L., Washington, D. C.
Quinn, Mrs. I. T., Montgomery, Ala.

Rhodes, E. C., Morgantown, N. C.
Richardson, A. A., Columbia, S. C.
Robertson, A. W., Lexington, Va.
Robertson, Mrs. A. W., Lexington, Va
Robertson, Roy L., College Park, Md.
Rucker, H. C., Salisbury, N. C.
Ruhl, H. D., Lansing, Mich.
Ruhl, Mrs. H. D., Lansing, Mich.
Rutherford, R. M., Washington, D. C.

Sawtelle, William H., Phoenix, Ariz.
Sawtelle, Mrs. William, Phoenix, Ariz.
Schoffman, R. J., Bourbommais, Ill.
Scott, S. A., Wytheville, Va.
Seely, T. S., Gainsville, Ga.
Shaw, A. C., Atlanta, Ga.
Shilling, E. A., Atlanta, Ga.
Sieling, Fred W., Solomons Island, Md.
Silver, James, Atlanta, Ga.
Silver, Jamie, Atlanta, Ga.
Simmons, V. M., Indianapolis, Ind.
Skaggs, Luther, Marion, N. C.
Skaggs, William R., Franklin, N. C.
Snow, William S., Richmond, Va.
Stephens, E. Sydney, Columbia, Mo.
Stras, B. W., Jr., Tazewell, Va.
Stucke, E. W., Philadelphia, Pa.
Stupka, Arthur, Gatlinburg, Tenn.

Tidd, Wilbur, Columbus, Ohio

Van Oosten, Mrs. John, Ann Arbor, Mich.

Wakefield, S. A., Shelbyville, Ky.
Weaver, Beulah, Raleigh, N. C.
West, Rupert E., Moyock, N. C.
Wiant, C. R., Marion, Ala.
Wickliff, Mrs. E. L., Columbus, Ohio
Williams, R. W., Washington, D. C.
Woodward, Hugh B., Albuquerque, New Mex.

# OPENING ADDRESS

PRESIDENT QUINN: The Sixty-eighth Annual Convention of the American Fisheries Society will be in order.

I am not going to impose upon you a long discussion by way of introduction of myself as President of this Society. We have reached a point in this country when it behooves all practical men, all scientific men and technicians, to bend every effort toward setting up a program of restoration and development of the fisheries of this Nation. You know and I know that an ever increasing number of people are clamoring for an opportunity to get out into the open and to utilize their additional spare time for recreation. Because of prevailing trends in working hours the amount of time available for outdoor recreation will increase as the years go by.

The demands for facilities for out-door recreation come to us as administrators, as research workers, as men engaged in scientific work. Furthermore, with an increase in our population more and more demands are being made each year upon those who are engaged in the conservation and development of our commercial fisheries, for this food resource is growing in importance.

It is necessary, therefore, that we do everything we can as administrators, scientists, and culturists, producing fish both for sport and for commerce, to combine our efforts in setting up such a program that will meet the future demands.

The American Fisheries Society, which today celebrates its sixty-eighth anniversary, has done more, in my opinion, than any other conservation group in America over so long a period to attain the ends and purposes for which the Society was originally founded; and we may congratulate ourselves today, ladies and gentlemen, on the fact that that responsibility today rests on our shoulders, to carry on in the field which our forefathers, in founding the Society, had in mind.

I hope that this program will be executed with dispatch, that our attendance at these sessions will be prompt, and that we will be ready and prepared to respond when we are called upon. I think that one of the finest indices to a man's character and love for his work is to learn whether he is on time, prompt and punctual; whether he makes it a cardinal principle in life at all times to be punctual.

I am going to call for the reports of the officers of the Society at this time. The first will be the report from our Secretary-Treasurer.

# REPORTS OF OFFICERS

## REPORT OF THE SECRETARY-TREASURER

For the Year 1937-1938

SETH GORDON

The report this year is somewhat more encouraging in a number of respects than that of last year. Our net gain in members is eighteen, whereas that of last year was only eight. It is gratifying to report the addition of four states and Newfoundland to our list of new members, a net gain of four over last year. A special drive to enroll all the state and provincial departments has been uppermost in our minds this year.

There are now only thirteen states which do not hold membership in the Society. Of these thirteen, four have put through state vouchers for their dues, which I am sure your Secretary-Treasurer will receive very shortly. By next year, I hope it may be the Secretary's privilege to report 100 per cent membership for the states. More of the Canadian provinces also should be persuaded to take an active part in the work of the Society by affiliating.

Through the efforts of our officers and members, in addition to the five state members above mentioned, we added eighty-two active members, eight libraries and three clubs and dealers. Our losses were seventy-six, but since we were obliged to close our books June 15, because the annual meeting was advanced, we hope many of the members dropped for dues may return to the list during this meeting.

The sale of back issues of the Transactions has been very encouraging, which proves that our proceedings are getting wider distribution and being used more and more as reference volumes in university and other libraries.

I want to take this opportunity to congratulate the Chairman and other members of the Publications Committee for the splendid work they have done to improve the standard of our Transactions, and to produce a volume more uniform in style. The printing of the "Suggestions for Preparing Papers" has been of great assistance to the Committee. This is further reflected in the style and the more careful preparation of the papers presented for this annual meeting.

Your Executive Committee held a special meeting at Baltimore in February during the North American Wildlife Conference, at which time the wisdom of adhering to a definite annual meeting period was discussed. The desirability of holding the annual meetings of the Society at a fixed place each year also was weighed. The Committee decided to query the members of the Society upon these questions, and to invite suggestions for the further improvement of the work of the Society.

While fewer responses were received than anticipated, the replies represent a good cross-section of the Society's membership. Of these responses, 24 per cent indicated a preference for June as the month for the annual meetings, 19 per cent suggested August, and 39 per cent recommended the first half of September. The balance named various other months.

Relative to the question of holding the meetings at a fixed place or shifting them annually, as in the past, 25 per cent suggested a fixed place and 75 per cent favored changing the place of meeting annually to bring these sessions to the several regions of North America.

These matters deserve further consideration by the Society, but the expressed preferences are quite clear.

Many helpful suggestions for improving the meetings and the activities of the Society in general were received. They have been laid before the Executive Committee for consideration.

While the balance in the bank of $746.79 as of June 15, 1938, is not so large as that reported at the close of the year June 30, 1937, it must be remembered that because we advanced our date for the annual meeting from late August or early September to June it was not practical to mail out bills for dues for the fiscal year 1938-39. Had this been done, the Treasury would be in a much stronger condition. Because the size of the proceedings of the Grand Rapids meeting was much larger than anticipated, the printing bill for that issue was considerably higher than usual, and the expenses for this item are part of the disbursements for the year 1937-38.

We have in our permanent fund $1,226.97. There have been no expenditures from this fund during the past year. The complete report is submitted as follows:

## TREASURER'S REPORT

### July 1, 1937 to June 15, 1938[1]

### GENERAL FUND

**Receipts**

| | | | |
|---|---|---|---|
| Balance on hand July 1, 1937 | | | $ 841.56 |
| Annual Dues: | | | |
| Individuals: | | | |
| For the year | 1934-1935 | $ 3.00 | |
| | 1935-1936 | 15.00 | |
| | 1936-1937 | 105.00 | |
| | 1937-1938 | 1,044.00 | |
| | 1938-1939 | 33.00 | 1,200.00 |
| Libraries | | | |
| For the year | 1936-1937 | 14.00 | |
| | 1937-1938 | 48.00 | |
| | 1938-1939 | 2.00 | 64.00 |
| Clubs and Dealers | | | |
| For the year | 1936-1937 | 15.00 | |
| | 1937-1938 | 85.00 | 100.00 |
| State Membership | | | |
| For the year | 1937-1938 | | 620.00 |
| Sale of Transactions | | | 248.83 |
| Sale of Index | | | 5.00 |
| Sale of Separates: | | | |
| 1935 Transactions | | 7.44 | |
| 1936 Transactions | | 432.87 | 440.31 |
| Exchange on Checks | | | .30 |
| Total Receipts | | | $3,520.00 |

[1]Since the annual meeting was advanced to June it was necessary to close the books on June 15, 1938.

DISBURSEMENTS

| | | |
|---|---|---|
| Transactions: | | |
| 1936, Vol. 66 | | |
| Printing and Cuts | $1,559.06 | |
| Indexing | 109.44 | |
| Reprints | 442.70 | $2,111.20 |
| 1937, Vol. 67 | | |
| Reporting | | 46.81 |
| Rental Safe Deposit Box | | 5.50 |
| Exchange on Checks | | 2.23 |
| Clerical and Secretarial Expense | | |
| Seth Gordon | 100.00 | |
| Ethel M. Quee | 200.00 | |
| Extra assistance | 23.44 | 323.44 |
| Stationery and Printing | | 76.83 |
| Postage | | 111.71 |
| Telephone | | 1.85 |
| Telegraph | | 3.82 |
| Office Supplies | | 17.43 |
| Traveling Expense | | 13.98 |
| General Expense | | 19.50 |
| Express | | 9.16 |
| Premium on Bond | | 18.75 |
| Refund on Transactions | | 6.00 |
| Total Disbursements | | $2,768.21 |
| Total Receipts General Fund | $3,520.00 | |
| Total Disbursements General Fund | 2,768.21 | |
| Balance on hand June 15, 1938 | | [2]$ 751.79 |

## PERMANENT FUND

RECEIPTS

| | | |
|---|---|---|
| Balance on hand July 1, 1937 | | $ 926.45 |
| Interest on Savings Account | $19.68 | |
| Interest on Mortgage Certificates | 250.84 | |
| Dividends on Commonwealth Southern pfd. | 30.00 | 300.52 |
| Total Receipts | | $1,226.97 |

DISBURSEMENTS

None

| | |
|---|---|
| Balance on hand June 15, 1938 | $1,226.97 |
| Par value of Certificates | 5,000.00 |
| Par value 10 shares Commonwealth Southern, pfd. at $100 each | 1,000.00 |
| Total | [3]$6,000.00 |

| | |
|---|---|
| [2]Balance in Bank June 15, 1938 | $746.79 |
| Balance in Petty Cash Fund | 5.00 |
| | $751.79 |

[3]The market value of certificates during the past year has been far below par, but since there is no open market no established cash value is available. The cash value of the 10 shares of Commonwealth Southern Preferred, par value $100, as of June 15, 1938, was $370.00.

## REPORT OF THE LIBRARIAN

Kenneth E. Cobb

It will no doubt be of interest to members of the Society to know that during the past year orders have been received, for partial and as near complete sets as are available, from Japan, South Africa and Russia. The increase in orders for volumes from University Libraries has also been noticeable.

Copies of Transactions on hand July 1, 1938 and available for sale:

| Year | Number on hand | Year | Number on hand |
|---|---|---|---|
| 1895 | 6 | 1920 | 112 |
| 1896 | 17 | 1921 | 65 |
| 1897 | 35 | 1922 | 60 |
| 1898 | 38 | 1923 | 54 |
| 1904 | 24 | 1924 | 173 |
| 1906 | 117 | 1925 | 258 |
| 1907 | 107 | 1926 | 186 |
| 1908 | 118 | 1927 | 157 |
| 1909 | 88 | 1928 | 140 |
| 1910 | 83 | 1929 | 171 |
| 1911 | 77 | 1930 | 169 |
| 1912 | 138 | 1931 | 174 |
| 1913 | 161 | 1932 | 194 |
| 1914 | 7 | 1933 | 121 |
| 1915 | 8 | 1934 | 97 |
| 1917 | 48 | 1935 | 49 |
| 1918 | 25 | 1936 | 75 |
| 1919 | 131 | | |

| | |
|---|---|
| Cloth Bound Index | 139 |
| Paper Bound Index | 216 |

Copies of volumes for the following years are needed to complete our file for the permanent library: 1876-1877-1878-1879-1880-1881-1882-1883-1884-1887.

The Society asks that members having extra copies of volumes for these years send them to the Librarian for our permanent library.

# REPORTS OF VICE-PRESIDENTS OF DIVISIONS

## REPORT OF THE DIVISION OF FISH CULTURE

Joe Hogan

In preparing this report for the Society I have checked over previous reports of the Division of Fish Culture for several years past. The previous reports have dealt with fish culture problems and practices in our hatcheries, and, to a more limited extent, with the abuses of pollution and drainage, and the need for trained personnel for fisheries conservation work.

This Society was organized in 1870 (1) to promote the cause of fish culture; (2) to gather and diffuse information of a scientific character; and (3) to encourage those interested in fish culture and fisheries problems. With reference to these three objectives I believe we have been the most lax in the promotion of the cause of fish culture and its relationship to

our public waters. Probably this laxity has been due to stiffer opposition and more complications than confronted the other objectives of the Society. The scientific men engaged in research work of all kinds have made outstanding contributions to fisheries science and there has been no lack of enthusiasm on the part of administrators and hatchery men with respect to fish propagation.

The entire responsibility for seeing that our fish are given consideration in proportion to their economic importance rests with no certain class of workers. No one group is responsible for the promotion of the cause of fish culture. With a true perspective of the problems, the fisheries administrator, the scientific research man, the practical fish culturist, the Biological Survey, public health departments, the sport fishermen and commercial fishermen can all work effectively and in harmony in their respective fields. The cause of fish culture must have the cooperative efforts of these men to succeed.

Fish culture as it is practiced in our hatcheries, without due consideration for clean public waters for stocking and fishing, is not the answer to our problems. With the increased demand upon our waters each year for more fishing, the trend must be toward enlargement and improvement of the water areas open to the public, instead of diminution and pollution. The perfection of our fisheries management and an increase in public fishing areas are demanded by the public—and justly so.

The gradual recession of fishing waters has occurred not because fish culture is unworthy but rather because of encroachment by special interests which have profited thereby. A temporary financial gain by an individual or corporation has eclipsed the issue and fish-life has received little or no consideration. For example, pollutants have been dumped into the waters because it costs money to build rectifying or disposal plants, and large scale drainage districts have been created at the insistence of promoters under the guise of improvements. During those years when drainage of any tract of land was considered an improvement, and pollution laws could not be enforced without danger of losing an industry, little apprehension could be aroused by the destruction of fish-life. Certain quantities of organic pollution may be beneficial to aquatic life and drainage of fertile tillable land may be an improvement if both practices are regulated within the bounds of reason. The fad of drainage in some sections of the country had to continue until the last stages of the program were endangering the future prosperity of the Nation by lowering to a dangerous level the water supply needed for human habitation.

At the present time the American people are about to awaken and realize the value of water and its importance in our economic welfare. Efficient farming methods have been developed and stressed until today the annual crop production is in excess of the country's needs, and land values have decreased. On the other hand the actual value of water areas has increased until today a good lake can be sold at a premium.

The Nation is becoming water-wise. The era of drainage at any price has about run its course, and water conservation on a large scale is being planned. On our major water-sheds, large reservoirs are being planned and built in order to combat floods. If all these plans are carried out, within the next few years millions of dollars will be spent in an attempt to regulate the flow of water in many sections of the country. Water reservoirs are being built by cities, corporations, and individuals. No park or recreational area is complete without a lake, either natural or artificial. Public officials, machinery companies, construction companies, engineers, contractors, farmers, and laborers, and many other citizens who in the past did not have a sympathetic attitude toward water conservation and fisheries problems are directly interested in this movement.

Water is being conserved for navigation, irrigation, flood control, drought control, hydro-electric plants, various industrial purposes, municipal water

supplies, boating, bathing, fishing, shooting marshes and many other purposes. With a few exceptions, such as the adverse effect of high dams on anadromous fishes, all water conservation projects can be utilized as additions to our existing fishing waters if properly constructed and managed.

Hand in hand with water conservation goes the future of our public fishing waters. When new projects are erected on our water courses every possible effort should be exerted to have the construction and subsequent management so planned that a maximum annual yield of fish can be produced in addition to the accomplishment of the objective of flood control or whatever other primary motive influenced the project.

The movement toward the conservation of fish-life cannot succeed without the sympathy of the public. I believe we have that sympathy now. The loss of suitable waters, and consequently the fish-life, emphasizes their value now, and as a result there are now enough conservation-minded citizens to assure the progress of improvement and restoration. Those of us interested in fish culture, fisheries science, or fishing should all join in the spirit of the founders of the Society and help to promote, over the entire country, the cause of fish culture.

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## REPORT OF THE DIVISION OF AQUATIC BIOLOGY AND PHYSICS

EUGENE W. SURBER

A survey of current trends in fresh-water biology and fisheries research has been made through an examination of the leading periodicals. This survey is incomplete, but the work of actually attempting it has been very interesting, and it is hoped that some of the general findings will be of value to members of this Society.

The survey was begun with a perusal of the Transactions of this Society for the period from 1927 to 1936, including the latest publication which has been received. Of the 372 articles placed in various categories, the greatest number (15.8 per cent) dealt with trout culture. In this field the feeding of trout received most attention, and parasites and diseases ranked second in importance. The progress made in trout feeding during the past decade has been rapid. We have learned much concerning the use of dry meals as meat substitutes and the fundamental nutritional requirements of trout. The culture of bass (14.8 per cent of the papers) was next in importance, and the phases of bass culture, which have recently received greatest attention are, as we all know, artificial feeding and the control of parasites, diseases, and enemies. Salmon investigations in their various phases ranked third in the number of articles published. Other important subjects which constituted from 4 to 6 per cent of the articles published are, in order, general fish culture, life-history and habitat studies, pollution, fish distribution and migrations, invention of hatchery devices, fish ladders and other equipment, and chemical and physical factors that affect fish directly or indirectly.

New phases of fisheries research such as the culture of forage fishes, walleyed pike, and muskellunge; creel censuses and natural productivity studies; and the problems of the commercial fisheries of the Great Lakes contributed few but important articles. It is well known that stream improvement and the rearing of trout to large size have occupied the attention of fish-culturists and fisheries biologists everywhere, yet there has been little discussion of these subjects at the meetings of this Society or in the *Progressive Fish Culturist*. This lack of discussion is probably due to the fact that much of the work on stream improvement, for example, has been published or described in state reports, or to the fact that sufficient time has not elapsed to evaluate the results of these new investigations.

*The Salmon and Trout Magazine*, 1935-1938, Fishmonger's Hall, London.—*Salmon and Trout Magazine* is an angler's publication which maintains a close contact with fresh-water biologists, and many interesting articles appear in it concerning the stocking of trout, pollution, trout culture, parasites and diseases of trout. The editor of the biological notes, Dr. Wilfred Rushton, who recently attended an annual meeting of this Society, appears to be particularly interested in pollution. Miscellaneous articles dealing with salmon, trout culture, angling for salmon and trout, pollution, and trout stocking have predominated among articles published in the magazine during the period 1935 to 1938.

*Bulletin Francais de Pisciculture*. 1936-1937, Orleans, France.—This is a monthly publication devoted to fish culture, and the articles that appeared between August, 1936, and June, 1937, dealt with trout culture, fish management, salmon, carp culture, parasites and diseases of fish, and aquatic insects with no particular emphasis on any one phase.

*Internationale Revue der gesamten Hydrobiologie und Hydrographie*, Leipzig, Germany.—This journal typifies an American need in which articles in pure aquatic biology predominate. Studies of Entomostraca and other crustacea, limnology (chemical and physical factors in lakes and streams, and bottom fauna of lakes), and studies of aquatic insects, principally Diptera and Trichoptera, predominated in recent numbers. Articles dealing with productivity in pond-fish culture have appeared also.

*The Progressive Fish Culturist*. U. S. Bureau of Fisheries, Washington, D. C. —Although not scientifically recognized as a publication, this well-known monthly multilithed journal is already regularly received by more than one thousand persons interested in fish culture. The number on the mailing list indicates popular approval and the need for such a journal. The chief emphasis has been placed on trout culture (30.0 per cent), bass culture (14.3 per cent), the stocking of trout and other species (9.9 per cent), and fish management (8.4 per cent). Here again the nutrition of trout has received greater attention than any other single item. The fact that the percentages are small indicates the diversity of subject matter discussed in the periodical.

*Publications of the U. S. Bureau of Fisheries*, 1927-1938. Washington, D. C. —One hundred twenty-seven articles published from 1927 to 1938, aside from administrative reports and statistical reports of the Division of Fisheries Industries, show that the greatest emphasis has been placed on (1) marine fisheries investigations (36.2 per cent), (2) oyster investigations (19.7 per cent), and (3) technological studies (19.7 per cent). Other fields received considerably less attention. When the value of sport fishing is considered, it does not seem that fresh-water biology and aquicultural research are receiving their due share of attention by our Government.

*Journal of the Biological Board of Canada*. 1934-1938. Toronto, Canada.—Technological studies and salmon investigations lead in the number of articles presented in this journal from 1934 to 1938. Although articles appearing in the *University of Toronto Studies* deal primarily with fresh-water biology and the fisheries, no very recent survey has been made of this journal.

*Zeitschrift für Fischerei*. 1936-1938. Berlin, Germany.—Current publications (1936 to 1938) in this journal are more closely related to fish culture than those in the *Internationale Revue*. The detail with which most of the studies are carried out is amazing, and reflects faunistic training and knowledge that few aquatic biologists in this country possess. Examples of recent studies are the following: Studies concerning the annual and daily swarms of insects over carp ponds; a study of the food of fish-food organisms in eutrophic lakes; a study of the food of trout enemies and trout associates at a fish-cultural station; migrations of fresh-water fishes; a chemical study of ensilage fed to carp; a detailed study of *Costia necatrix*, a parasite of carp; a biometrical study of the carp; the effects of fertilizers on the gills and skin of carp and trout; a classification

of lakes and ponds based on production; the morphology of brook trout; the food of carp; and anatomical studies.

*Archiv für Hydrobiologie.* 1935-1937. Stuttgart.—This is a journal of aquatic biology in which the chief emphasis during the past three years (1935 to 1937) has been on (1) limnological investigations (including chemical and physical factors in aquatic biology), and (2) the crustacea (Entomostraca and Malacostraca). In studies of aquatic organisms the most important contributions concern the Rotifera, Hydracarina, and Diptera. Again one is impressed by the detailed faunistic knowledge of German fresh-water investigators, which emphasizes the need of more thorough training for the aquatic biologists in fisheries work in this country.

In a survey of literature of this kind, one is impressed by its bulk. Further compilations and observations have been made but these will not be mentioned here.

There is a need for an American publication in which fresh-water biologists in this country may publish articles concerning the more theoretical, abstract, and less immediately practical phases of fresh-water biology. Perhaps the Limnological Society of America, recently organized, will eventually provide the means through the medium of its own publication. At the present time we find many of our prominent aquatic biologists publishing articles in a large number of different journals, both in this country and abroad, in such publications as *Archiv für Hydrobiologie* and *Internationale Revue der gesamten Hydrobiologie und Hydrographie.* This lack of a suitable American journal is a handicap to research, for articles thus scattered in publications all over the globe make them difficult of access unless one is located at a University or near good libraries.

Until such time when an American journal of limnology appears, I suggest that this Society provide for an annual review of current literature in aquiculture and fresh-water biology; that this review consist merely of the listing of titles of papers that appeared in the different fields during the preceding year only. Marine studies might be included. It is suggested that not a committee, but one individual, perhaps the vice-president of this division, do this job. A great aid to this work would be the monthly report of recent accessions to the library of the U. S. Bureau of Fisheries. On the basis of his experience in this survey, the writer suggests the following categories for the classification of articles.

### Classification of Titles

1. Bacteria
2. Algae (filamentous, epiphytic, etc.)
3. Plankton
   - a. Zooplankton
   - b. Phytoplankton
   - c. General
4. Higher Aquatic Plants
5. Limnological Studies
6. Oceanography
7. Aquatic Animals
   - a. Protozoa
   - b. Porifera (sponges)
   - c. Coelenterata
   - d. Platyhelminthes
   - e. Nemathelminthes
   - f. Rotifera
   - g. Annelida
   - h. Mollusca
   - i. Crustacea
   - j. Hydracarina
   - k. Insecta
     - (1) Ephemerida
     - (2) Odonata
     - (3) Plecoptera
     - (4) Hemiptera
     - (5) Coleoptera
     - (6) Trichoptera
     - (7) Lepidoptera
     - (8) Diptera
   - l. Bryozoa
   - m. Vertebrates
8. Investigations in Aquiculture
   - a. Pond-fish culture
   - b. Trout culture
   - c. Fish diseases
   - d. Nutritional studies
   - e. Stocking of trout
   - f. Stocking of pond fish.
9. Parasites and Diseases of Fish
10. Commercial and Game Fisheries of Inland Waters

11. Oyster Investigations
12. Technological Studies
13. Salmon Investigations
14. Pacific Coast and Alaska Fishery Investigations (including studies of salmon, razor clam)
15. North and Middle Atlantic Fishery Investigations
16. South Atlantic and Gulf Fishery Investigations (includes shrimp, turtle studies)
17. Apparatus and Equipment
18. Biological Productivity (creel censuses, quantitative bottom fauna studies, etc.)
19. Pollution
20. Fishes
    a. Classification, description of new species, habits, etc.
        (1) Marine
        (2) Fresh-water
    b. Age and growth
        (1) Marine
        (2) Fresh-water
    c. Distribution and Migrations
        (1) Marine
        (2) Fresh-water
    d. Physiological Studies
        (1) Marine
        (2) Fresh-water
    e. Anatomical Studies
        (1) Marine
        (2) Fresh-water
    f. Food Studies
21. Physiological Studies of Invertebrate Animals
    a. Marine
    b. Fresh-water

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## REPORT OF THE DIVISION OF COMMERCIAL FISHING

HILARY J. DEASON

[Dr. Deason was appointed to succeed the late Lester Smith, who held the vice-presidency of the Division of Commercial Fishing.]

It has been demonstrated repeatedly that the statistics of the total annual yield of the fisheries are valuable from an economic standpoint, but as measures of abundance are of limited use to the conservationist and fisheries biologist. Our commercial fisheries production continues to increase, for the most part, because of the expansion of the physical side of the industry rather than because of the increase in natural abundance of the principal species.

Some of the causes of expansion are increases in the number of men employed, the number of boats, and the amount of fishing gear operated; improvements in the efficiency of fishing gear, the marketing of new species formerly considered of little value, and the development of new by-products.

I will not quote production figures; you all know where they are published should you wish to consult them. However, during the past year there have been numerous important developments which are related directly or indirectly to the ever-expanding fishing industry. It is believed that a brief discussion of some of them will fulfill the objective of the Society in calling for this report.

*Conferences.* The current report of the Committee on Foreign Relations discusses those fisheries conferences that were concerned with international questions. These meetings need not be listed. However, two conferences on interstate fisheries questions held during the year will be discussed briefly.

The New York Joint Legislative Committee on Interstate Cooperation held a meeting in New York City on September 10, 1937, to consider means of preserving the supply of game and food fishes in Atlantic coastal waters. A compact among the States of Massachusetts, Rhode Island, Connecticut, New Jersey, and Delaware was endorsed by resolution. The resolution suggested that a single administrative agency, in which each state is represented, be established to regulate the fisheries. Over-fishing was cited as the most important cause of depletion of the principal species, although pollution of rivers and inshore waters and the construction of dams were held to be deleterious to the stock of some species.

At a meeting of a special committee on Lake Michigan fisheries held in Chicago on May 6, 1938, attended by representatives of Wisconsin, Michigan, In-

diana, Illinois, and the U. S. Bureau of Fisheries, uniform regulations for the commercial fisheries were drawn up and recommended for enactment by the legislatures of the several states. The conference was sponsored by the Council of State Governments and was held at the central offices of that organization. The delegates reached complete accord on all important questions concerning the regulation of the commercial fisheries. Uniform laws were recommended covering size of mesh in commercial gear, size limits, and closed seasons for the important commercial species.

*Legislation.* A number of bills and joint resolutions which affect the commercial fisheries were under consideration by the Seventy-fifth Congress of the United States during the past year. Those of most importance to the industry are:

1. A bill to establish a fishery credit corporation, to promote the cooperative production and merchandising of aquatic products in interstate and foreign commerce. Not passed.
2. A bill to limit the licensing of vessels engaged in catching, killing, or processing whales or in catching, killing or processing other aquatic species. Not passed.
3. A bill to protect and preserve the salmon fishery of Alaska, which is specifically designed to protect the fisheries of Bristol Bay from foreign invasion. Not passed.
4. A joint resolution authorizing an investigation of the fisheries and the fishing industry of the Great Lakes. Passed.
5. An act to prevent aliens from fishing in the waters of Alaska. Not passed.
6. A bill which provides that certain articles represented as "lobster" shall be deemed misbranded within the meaning of the Pure Food and Drug Act. Not passed.
7. A bill to conserve lobsters and to regulate their interstate transportation. Not passed.
8. A bill for the promotion of oyster culture in Alaska. Passed.
9. A bill for the protection of female blue crabs in any State or Territory. Not passed.
10. A joint resolution to authorize compacts or agreements between the states bordering the Great Lakes with respect to the regulation of the commercial fisheries of the Great Lakes. Such agreements are not to be binding upon the several states until they have been approved by the legislatures of the states and by the Congress of the United States. Passed.
11. The wage and hour bill. Passed, but with an amendment excluding all phases of the fishing industry.
12. A joint resolution authorizing the committee on merchant and marine to make studies of the fishing industry during the present recess of Congress. Passed.
13. A bill authorizing the purchase of surplus fish to begin immediately. Passed. A sum of approximately $300,000 is to be spent before July 1.
14. A number of bills related to the American Merchant Marine Act, which would affect commercial fishing, were not passed.
15. A bill providing for a five-year program for the Bureau of Fisheries which is essentially a construction and maintenance bill providing for new hatcheries and laboratories. Passed and signed by the President.

*Discretionary Power Act in Wisconsin.* A completely new departure from the usual method of commercial fisheries regulation on the Great Lakes is found in the recently inaugurated "Discretionary Power Act" in Wisconsin. This act gives to the Conservation Department the power to regulate the fisheries by executive order. Formerly all fisheries regulations were contained in laws passed by the State Legislature and could be changed only by legislative action. Under the discretionary power act new regulations are submitted to the governor for signature before they become effective, and may be changed and amended at any time in order to meet the needs of the fisheries.

The former method of regulation lacked the flexibility necessary to meet emergency conditions in the fisheries. Many of the early laws were not framed in conformity either with the practical experience of commercial fishermen or the facts brought out by careful scientific investigation. Even the best regulations were frequently enacted too late to prevent the disastrous depletion of important species. Consequently the history of Wisconsin fisheries, those of the other Great Lakes states, and of state-controlled marine areas has often been one of a continuous decline.

Fisheries for some species now commercially extinct can probably never be restored, but careful and prompt regulation, which is only possible through discretionary power, may be expected to bring the fishery to a far healthier state than it has enjoyed for many years. Discretionary power is recommended to all states charged with the regulation of commercial fisheries.

*Pilchard Investigations.* The pilchard, or California sardine, supports an annual production of over a billion pounds. The increased exploitation to which the fishery has been subjected during recent years has given rise to fears that the strain through fishing intensity may be greater than the population can support. Some believe that the fishery is taking an undue toll of immature individuals, thereby endangering the spawning reserve.

In accordance with a special act and appropriation authorized by the Seventy-fifth Congress, the U. S. Bureau of Fisheries has undertaken a comprehensive investigation of the pilchard fishery. The primary purpose of the current work is to determine whether over-exploitation exists and what form of regulation will be necessary to conserve the resource. Many purely scientific data must be accumulated and interpreted before concrete results can be expected. An interesting feature of the investigation is the use of airplanes in an attempt to discover whether unexploited units of the pilchard population exist in waters not frequented by commercial fishermen.

*Fish Market News Service.* The Seventy-fifth Congress authorized and provided a special appropriation for the inauguration of a fishery market news service at some of the principal commercial fishing centers. Although new to the fisheries, this type of federal service has been conducted for agricultural communities for more than twenty years and has proven to be both valuable and popular. The first fishery market report was issued in New York City on February 14, 1938, and the service was inaugurated in Boston in May. Later, reports will be issued at Seattle and Chicago. The daily bulletins include such data as hailing fares, prices, supply, market, and demand for commodities; cold storage movement and holdings; and imports of fishery products. Each report also includes summarized information relative to markets elsewhere in the United States. The success of this service is attested by the approval voiced by fishery associations, wholesale fish dealers, cold-storage and freezing companies, transportation agencies, financing companies, Federal, State, and Canadian fishery agencies, fishermen, reporters and editors of newspapers and periodicals.

*Improvements in Boats and Equipment.* There have been no outstanding innovations in the equipment of fishing boats or in fishing methods during the year. However, each new boat launched incorporates newly designed equipment not only for convenience and efficiency in handling the vessel but also for the efficient operation of fishing gear and the preservation of the catch. Much more attention is paid to lining the holds with non-corrosive materials which greatly improve sanitary conditions in comparison with those of a few years ago.

Among the recent improvements in fishing gear is the development of a pneumatic float for trawls which eliminates much debris in the catch and helps to prevent snagging on obstructed grounds. The perfection of a new inexpensive float for gill nets to replace the cedar floats which require frequent oiling and baking to keep them in serviceable condition, although still in the experimental stage, promises to be successful. The use of small, strongly constructed pounds for crabs has been inaugurated, and promises to replace methods formerly used in the fishery, especially in certain areas where there are strong currents.

*Processing and Marketing.* Improvements in methods of filleting, freezing, and packaging fisheries products are constantly being made under the guidance of researches conducted by the industry and by governmental agencies. Wherever feasible factory production methods are being inaugurated which produce a more uniform and sanitary product. The fresh fish industry has accepted two new inventions, one of which is a hydraulic fish scaling machine which can handle as many fish as several men using electric scaling machines. A completely automatic filleting machine is being used to a small extent but is still largely in the experimental stage. The industry has not accepted it because the waste is much greater than in hand filleting. The second new machine to be accepted is one for the manufacture of crushed ice. This machine has been developed under at least three independent patents. The crushed ice produced takes the form of "flake," "snow," or "flower" particles, depending on the type of machine used. Each machine produces ice as it is needed. The prevention of waste incident to melting of stored artificial ice, the elimination of transportation costs, and the elimination of ice-crushing machinery have appealed to the shippers of fresh fish who have adopted these devices.

*Technological Research.* The research conducted by fisheries concerns, government laboratories, and pharmaceutical laboratories has continued to progress throughout the year. Although no outstanding developments have come to our attention, many improvements in the constitution and perfection of commercial fisheries products and by-products have been made. The improvement and expansion of the line of pharmaceutical products in which fish oils are employed is very noticeable. With the discovery of oils of much higher vitamin potency than the traditional cod liver oil and halibut liver oil, many other species of fishes are now providing liver and body oils which are marketed as such or are used to fortify, or increase the vitamin content of, cod and halibut oils.

Fish not only feed us but may also clothe us if the discoveries of a German scientist are put to practical application. His researches prove, so he asserts, that the albumen obtained from fish and shellfish is usable for the manufacture of a wool that is even better than wool itself. We may therefore forecast that the fish markets may also enter the cloak and suit business. Imagine the tremendous advertising appeal of a sport suit made from oysters, a knitted scarf from halibut, or an afternoon frock from carp! Other new developments will enable Madame to adorn her frock with a corsage of artificial flowers made from fish skins. On her hat she may wear as an ornament a dried and dyed fish swim bladder, for these are already on the market.

*Needs of the Industry.* A number of suggestions for the improvement of the commercial fishing industry, both from an economic standpoint and from the point of view of conservation are called to the attention of the Society:

1. Institution of systems of *management* of all commercial fisheries, where two or more states or countries are involved, through the formation of interstate or international commissions endowed with the necessary discretionary power to make and amend regulations as determined by the biological and statistical data accumulated under their supervision.
2. Control of production, a function of discretionary power, is a desirable conservation measure in many localities and will prevent both waste of products through glutted markets and the unnecessary and profitless depletion of fisheries populations.
3. Adequate control of wholesaling and merchandising systems including an attempt to curtail the frequently large margin of profit they exact. This control will result in fairer retail prices and a more equitable return to the producer, especially the small independent fisherman.
4. Improvement of retail marketing conditions and facilities, especially in inland communities where the consumption of fish is low not only because of high prices but because of the frequently poor and unpalatable condition of the merchandise.
5. Frozen fish are frequently thawed out by wholesalers and marketed as

freshly caught fish. Appropriate legislation requiring frozen fish to be so labeled in shipping and in retailing appears desirable.

6. Before any significant progress in conservation of the fishing industry can come about there must be better understanding between conservation officials, technical workers, and commercial fishermen. The conservation departments and fisheries biologists must be more conversant with the technical phases and practical problems connected with the industry so that they can *sell* a sound program to the fishermen. Unless the fishermen *want* conservation and subscribe to the thesis that a continuance of the industry is of more ultimate value than today's profit, there is no hope!

THE PRESIDENT: This report, in my mind, is one of tremendous importance, and I want to express my appreciation and the appreciation of the Society to Dr. Deason, because due to the fact that he was only recently appointed to fill the place of Mr. Smith he has had very little time to collect this information.

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## REPORT OF THE DIVISION OF PROTECTION AND LEGISLATION

B. M. BRENNAN

Legislative attention to the fishing resources of the Nation has, in the past, been largely directed toward regulation of the fisheries themselves; toward imposing bag limits, closed seasons, and other protective measures on the fisheries, with the object of curtailing the fishing intensity and thus preserving the fish stocks. This sort of legislation has had marked beneficial effects. However, these methods of regulation can only protect the fish populations within the limits of their existing ranges. The available habitat, however, is being steadily reduced as civilization and industrialization progress. This progress constantly introduces new and serious sources of mortality to the fish populations. Perhaps the major problem confronting us today is, therefore, the correction, or at least amelioration, of destructive influences on the inshore and inland fisheries.

Particularly harmful to the migratory and anadromous fishes is the industrial and agricultural development of the water resources. Many dams have been constructed, and many more are being constructed, which are barriers to the upstream migrations of salmonoid and other fishes. It is necessary that adequate fishways be provided over dams so that the areas above them will not become unavailable to the migratory fishes.

In addition to the development of the rivers for power, extensive projects for irrigation have been instituted. Unfortunately, when the water of a stream is diverted into the fields, the fish life of that stream is carried out with it, unless provision is made to prevent it. Tremendous losses of young salmon in the Columbia River drainage have occurred in this manner. Undoubtedly, similar losses have resulted from irrigation developments in other parts of the country. Installation of proper protective screening devices at the intakes of irrigation diversions is a costly process, but such protection must be provided if the fish populations of the streams are to be preserved.

The problems resulting from the industrial and agricultural development of our streams and rivers have long received the attention of legislative bodies as well as of fisheries workers. However, many of the best intentioned projects have been failures so far as the protection of the fish life is concerned. Too often fish ladders have been constructed without proper regard for biological and engineering facts and as a consequence have failed in their purpose. Similarly, screening of water diversions must take into account the habits, as well as the morphology, of the fish if the screens are to operate successfully and efficiently. These difficulties can be and have been overcome in many localities, however, by adequate research and planning, particularly in the western states.

The point to be kept in mind is that legislation is not effective without adequate planning.

The cost of installation of proper protective devices for the upstream and downstream migrants of the anadromous and other migratory fishes should be considered a part of the cost of the hydro-development, a part of the initial cost of the construction.

In connection with the damming of streams for irrigation and power developments, it is also imperative that a certain minimal flow be maintained at all times below such structures. Otherwise, the migrations of some species will be stopped and the habitat of others will be entirely destroyed.

In recent years considerable attention has been directed toward the industrial and domestic pollution of the inland and inshore waters. In addition to the direct toxic effects of many of these pollutants on the fish themselves, the available fish productive area may be markedly reduced by the ruining of spawning and feeding areas, and by the severance of migration paths by chemical barriers. Numerous states have passed legislation with the object of reducing the pollution load. A pressing need is evident, however, for a concerted and uniform pollution prevention program. The recent congressional interest in the matter is to be commended as a start toward the ultimate solution of this pressing problem of fish protection. Yet, national cooperation is only a beginning in the right direction. In the aggregate, the pollution problem, although vast, is made up of a large number of individual problems which must be solved by local agencies.

Another problem in the conservation of fish which should be mentioned is the need for intelligent and concerted protection of fish populations which are interstate in character. A fundamental principle in fisheries law is that the fish resources are the property of the states in which they occur, and their regulation is one of the sovereign rights of the states. While this principle operates very well where a fish stock is confined to a single state, it is unfortunately true that when several states have a joint interest the resulting legislation is often redundant and ineffective. However, as is illustrated by the example of the joint regulation of the Columbia River fisheries, there is no reason why cooperative management should not be efficient. We wish to urge that in other similar situations a proper cooperative attitude be assumed in order that the fish populations may be adequately protected.

The international problems of a similar nature are likewise not unsolvable. The success of the Pacific halibut regulations and the successful negotiation of a treaty for the protection of the Fraser River salmon point the way to the regulation of international fisheries resources.

# REPORTS OF STANDING COMMITTEES

## MINUTES OF EXECUTIVE COMMITTEE MEETINGS

*February 13, 1938*

The Executive Committee of the American Fisheries Society held a special meeting at the Hotel Lord Baltimore, Baltimore, Maryland, on February 13, 1938, beginning at 8:00 p.m., with members present as follows: Messrs. I. T. Quinn, Alabama, President; T. H. Langlois, Ohio, Second Vice-President; Seth Gordon, Pennsylvania, Secretary-Treasurer; Joe Hogan, Arkansas, Vice-President, Division of Fish Culture; and Eugene Surber, West Virginia, Vice-President, Division of Aquatic Biology and Physics.

Hon. John D. Chalk of North Carolina, Chairman of the Local Committee on Arrangements for the Sixty-eighth Annual Meeting at Asheville, N. C., June 23 and 24, 1938, also was present.

Members of the Committee unable to be present were: Messrs. Fred J. Foster,

Washington, First Vice-President; Kenneth E. Cobb, Connecticut, Librarian; Lester Smith, Wisconsin, Vice-President, Division of Commercial Fishing; B. M. Brennan, Washington, Vice-President, Division of Protection and Legislation; James Brown, Kentucky, Vice-President, Division of Angling; and A. G. Huntsman, Canada, President of the Society last year.

At the request of the President, Doctor Langlois outlined the topics announced for the Fisheries Sessions of the North American Wildlife Conference, beginning the following day, which were discussed in their relationship to the work of the Society. Upon motion made and adopted, it was agreed that while the Society should always cooperate to assure the success of such conferences, it should not act in the capacity of co-sponsor thereof.

The possibility of further consolidating various national and international conservation meetings was next discussed at length in an effort to determine whether the work of the several organizations might thereby be enhanced, and at the same time reduce the number of trips made by busy workers who are expected to attend numerous gatherings annually.

The Committee also discussed the wisdom of adhering to a fixed convenient meeting period annually, and the possibility that the work of the Society might be enhanced by agreeing upon a fixed meeting place conveniently located for the majority of the Society's membership. Certain members felt that shifting the meeting time as well as the place each year may be unwise.

Upon motion agreed to, it was decided to send a questionnaire to all the members of the Society to ascertain when would be the most convenient time for the majority of them to attend annual meetings; also whether they favored continuance of the present plan of holding the annual meeting in various parts of Canada, the United States, and Mexico, or whether they would prefer to meet each year at a convenient central point.

It also was decided to hold an open conference at Asheville, N. C., on Tuesday evening, June 21, following a meeting of the Executive Committee, for all members who can arrange to arrive by that date, to discuss the foregoing matters and to determine how best to increase the scope of activity and effectiveness of the American Fisheries Society.

Commissioner Chalk next outlined to the Committee his tentative plans to entertain the joint annual meeting of the Society and the International Association of Game, Fish and Conservation Commissioners at Asheville, beginning June 20, and the entire matter of local arrangements was left to Mr. Chalk and his Committee.

The Committee was informed that Dr. Ira N. Gabrielson, Chief of the U. S. Biological Survey, is planning a conference with all State game administrators on Wednesday, June 22, at Asheville, which will necessitate confining the sessions of the Society to two days, June 23 and 24. It was suggested that possibly Hon. Frank T. Bell, U. S. Commissioner of Fisheries, might desire to join with Chief Gabrielson in a joint conference with game and fish officials in advance of the opening session of the International Association, but since the possibility thereof is remote it was deemed best to adhere to the two-day sessions plan, and allow the Committee on Local Arrangements to utilize Wednesday, June 22, for field trips for those who may be free to participate therein.

The meeting adjourned at 11:30 p.m., and the Secretary was directed to send a copy of these minutes to all members of the Executive Committee and to Commissioner Chalk.

*June 21, 1938*

A called meeting of the Executive Committee of the American Fisheries Society was held at the Battery Park Hotel, Asheville, N. C., at 6:30 p.m. on June 21, 1938. Those present were: I. T. Quinn, Montgomery, Ala., President; Fred J. Foster, Seattle, Wash., First Vice-President; Seth Gordon, Harrisburg, Pa., Secretary-Treasurer; Eugene Surber, Leetown, W. Va., Vice-President, Division of Aquatic Biology and Physics; H. J. Deason, Ann Arbor, Mich., recently

appointed Vice-President of the Division of Commercial Fishing, succeeding the late Lester Smith of Port Washington, Wis.; and B. M. Brennan, Seattle, Wash., Vice-President, Division of Protection and Angling.

Members of the Committee unable to be present were Messrs. T. H. Langlois, Put-in-Bay, Ohio; Kenneth E. Cobb, Windsor Locks, Conn.; Joe Hogan, Lonoke, Ark.; James Brown, Frankfort, Ky.; and A. G. Huntsman, Toronto, Canada.

Present by invitation were Fred Westerman, Lansing, Mich., former President of the Society, and Ethel M. Quee, Assistant to the Secretary-Treasurer.

The discussions at the special meeting held in Baltimore last February were reviewed, and the results of the special canvas of the Society's membership relative to the most advantageous meeting period and the desirability of holding the annual meetings at a fixed place were discussed at length. The Secretary was directed to include the highlights of said survey in his annual report to the Society.

Upon motion made and agreed to, the Executive Committee decided to recommend that the Time and Place Committee endeavor to arrange the next annual meeting some time between August 20 and September 10, 1939, but to leave the matter of both time and place to that Committee's best judgment. (See report of the Time and Place Committee at end of Business Sessions.)

The wisdom of bringing the index of the Society's Annual Transactions up-to-date, published in 1929 to cover all transactions from the beginning to 1928 inclusive, was next considered. Upon motion made and adopted, it was agreed that the matter shall be referred to the Committee on Publications and the Secretary, with a request to jointly study the matter, including the prospective sale of a composite index to cover all transactions to 1938 inclusive, their recommendations to be submitted to the Executive Committee for approval.

Upon motion made and agreed to, the Secretary-Treasurer was instructed to invest $500.00 of the accumulated income in the Permanent Fund in U. S. Government Baby Bonds, and if part of such fund should later be needed to help defray the cost of the proposed index such portion of said investment as may be needed shall be sold at that time.

The desirability of placing the Society's permanent investments in the hands of the Trust Department of the Riggs National Bank of the District of Columbia for management was discussed fully. Upon motion made and adopted, the President and the Secretary-Treasurer were instructed to inquire into the matter, with power to handle the situation, and to sell and re-invest securities, as in their joint judgment as Trustees of said fund may be deemed best. It was further agreed that in the future, however, the Society's permanent funds shall be invested in Government Bonds. (Upon inquiry, the President and the Secretary-Treasurer decided not to place the Society's investments in the hands of the above banking institution because of the expense involved.)

There being no further business before the Executive Committee, the meeting adjourned at 8:45 p.m.

SETH GORDON,
*Secretary.*

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## REPORT OF THE COMMITTEE ON FOREIGN RELATIONS

JAMES A. RODD

The cordial and successful cooperation of the nations sharing the fisheries of this continent referred to in the recent reports of this committee has been continued and extended during the past year to include the sockeye salmon fisheries of the Fraser River system and the fisheries of the Great Lakes.

The dangers of overfishing are always present, even when a fishery is regulated and controlled by a single authority, and it is apparent to everyone that without mutual agreement in regard to policy the dangers of overfishing and depletion

are multiplied immeasurably when a fishery is prosecuted under the regulation and authority of more than one provincial, state, or national government.

The development of "factory" or "mother" ships; the partial exhaustion or decreased production of home banks; the expansion of fishery operations to the banks of other nations, sometimes at great distance from the home ports, has rendered the use of the "three-mile limit" entirely inadequate to control present situations in the fisheries and emphasizes the need for international agreements regarding extra-territorial waters resorted to by the citizens of several countries.

While the international cooperation on the North American continent for the preservation and care of the fisheries exploited jointly by the several nations has made steady progress, it would seem that the need for cooperation on a broader scale with nations elsewhere than on this continent has become a reality.

At the present time agreements have been reached or negotiations are under way in regard to most of the fisheries of major importance in the boundary waters contiguous to Canada and to the United States, all of which are referred to in this report or in previous reports of this Society.

The Foreign Relations Committee calls the attention of the Society to the most recent progress in regard to international agreements affecting the fisheries of the North American continent, as follows:

1. The exchange on July 28th, 1937, of ratifications of the Sockeye Salmon Fisheries Convention between Canada and the United States for the protection, preservation and extension of the sockeye salmon fisheries of the Fraser River system. The Convention provides for the establishment of the International Pacific Salmon Fisheries Commission, consisting of six members, three on the part of Canada and three on the part of the United States. The Commission is required to set up an Advisory Committee composed of five persons from each country who shall be representatives of the various branches of the industry (purse-seine, gill net, troll, sport fishing, and one other), which Advisory Committee shall be invited to all non-executive meetings of the Commission and shall be given full opportunity to examine and to be heard on all proposed orders, regulations or recommendations.

The duties of the Commission are defined in Article III as follows:

"The Commission shall make a thorough investigation into the natural history of the Fraser River sockeye salmon, into hatchery methods, spawning ground conditions and other related matters. It shall conduct the sockeye salmon fish cultural operations in the waters described in paragraphs numbered 2 and 3 of Article I of this Convention, and to that end it shall have power to improve spawning grounds, construct and maintain hatcheries, rearing ponds and other such facilities as it may determine to be necessary for the propagation of sockeye salmon in any of the waters covered by this Convention, and to stock any such waters with sockeye salmon by such methods as it may determine to be most advisable. The Commission shall also have authority to recommend to the Governments of the High Contracting Parties removing or otherwise overcoming obstructions to the ascent of sockeye salmon, that may now exist or may from time to time occur, in any of the waters covered by this Convention, where investigation may show such removal of or other action to overcome obstructions to be desirable. The Commission shall make an annual report to the two Governments as to the investigations which it has made and other action which it has taken in execution of the provisions of this Article, or of other Articles of this Convention.

"The cost of all work done pursuant to the provisions of this Article, or of other Articles of this Convention, including removing or otherwise overcoming obstructions that may be approved, shall be borne equally by the two Governments, and the said Governments agree to appropriate annually such money as each may deem desirable for such work in the light of the reports of the Commission."

The waters covered by this Convention are, in general, the Fraser River, Georgia Strait, the Straits of Juan de Fuca and certain territorial waters and high

seas westward from the entrance of Juan de Fuca Straits. In these waters the Commission (Article IV) is empowered to limit or prohibit the taking of sockeye salmon, and (Article V) in order to secure a proper escapement of sockeye salmon during the spring or chinook salmon fishing season, it may prescribe the size of the meshes of all fishing gears and appliances that may be operated during the said season. It is agreed under Article VII that each country should share equally in the fisheries and the Commission is consequently required to regulate the fisheries with a view to allowing as nearly as may be practical an equal portion of the fish that may be caught each year to be taken by the fishermen of each country. Under Article X, the High Contracting Parties agree to enact and enforce such legislation as may be necessary to make effective the provisions of the Convention and the orders and regulations adopted by the Commission under the authority thereof with appropriate penalties for violations.

2. The Great Lakes Fisheries Conference, called by the Council of State Governments, was held at Detroit, Michigan, on February 25 and 26, 1938, to consider better methods for the protection of the fisheries of the Great Lakes. The Conference was well attended by officials of the various states interested in these fisheries, the Province of Ontario, the United States Bureau of Fisheries, and the United States Department of State. Resolutions were adopted urging the appropriate agencies of the Federal Government of the United States to discuss with the appropriate Canadian authorities, without delay, the advisability of a treaty to establish an International Board of Inquiry whose function shall be to consider and to recommend measures for the conservation of the Great Lakes fisheries. The Conference also recommended such a treaty and urged the States in the meantime to take vigorous action individually and in cooperation with one another to conserve the fisheries of the Great Lakes.

3. As a result of discussions between the United States government and the government of Japan in regard to the salmon fishing activities of Japanese nationals in the offshore waters of Alaska, especially in the Bristol Bay area, reported during the past fishing season, the Japanese government has given without prejudice to the question of rights under international law, assurances as follows:

(a) That the Japanese Government is suspending the three-year salmon fishing survey which has been in progress since 1936 in the waters in question.

(b) That inasmuch as salmon fishing by Japanese vessels is not permitted without licenses from the Japanese Government and as the Government has been refraining from issuing such licenses to those vessels which desired to proceed to the Bristol Bay area to fish for salmon it will, on its own initiative, continue to suspend the issuance of such licenses; that in order to make effective this assurance, the Japanese Government is prepared to take, if and when conclusive evidence is presented that any Japanese vessels are engaged in salmon fishing on a commercial scale in the waters in question, necessary and proper measures to prevent any such further operations.

Your committee, however, wishes to point out that while the progress in investigation and agreement has been steady and extensive there remains the greater task of formulating and making effective the joint policies embodied in existing as well as in future agreements.

# REPORTS OF SPECIAL COMMITTEES

## REPORT OF THE POLLUTION STUDY COMMITTEE

TALBOTT DENMEAD, *Secretary*

A duty assigned to the Pollution Committee of the American Fisheries Society, of which I have the honor of being Secretary, was to follow up the so-called Lonergan anti-pollution bill, originally No. 13, when first introduced by Senator Lonergan, and endeavor to have it or some similar Federal anti-pollution Legislation passed by Congress.

A bill, originated from, or instigated by, the Lonergan measure, has just passed Congress, but it is not the law we wanted, or worked for. It will need substantial amendment at succeeding sessions of Congress, and the administration of what there is of it should be carefully watched. Efforts should be made to see that those selected to put the law into effect stay on the job, and do what the law tells them to do. Hence, it may be your wish to continue this Pollution Committee, which came into existence at the Montreal meeting several years ago.

Here is a brief resume of what the recently enacted law contains:

As you know, the Vinson bill passed the House, and the Barkley bill passed the Senate after amendments. The measure then went to conference. Senator Lonergan's bill was side-tracked by these other measures, which were primarily appropriation measures, authorizing the expenditure of a million dollars a year for investigations, etc., without any enforcement provision, nor any arrangement for State compacts, or loans for building sewage systems. About five sections of the Lonergan bill were inserted in the Senate, but the best of them were thrown out in conference. The most important omission, of course, is the lack of any enforcement provisions in the law as passed. In short, there is nothing in the passed bill that will actually clean up a lot of pollution.

The bill creates a Division of Water Pollution Control in the U. S. Public Health Service, in charge of a Director, who shall be a commissioned engineer officer of the U. S. Public Health Service, and he shall have the rank of an Assistant Surgeon General. He is to make investigations and prepare comprehensive plans for eliminating or reducing pollution. He will have a board of five commissioned engineer officers of the Public Health Service to advise him and help him out.

One of the duties of the Board will be to classify, as soon as possible, the navigable waters of the United States into districts, to be known as Sanitary Water Districts. Reports are to be prepared, printed, and submitted to Congress. The clause requiring the Board to fix a standard of purity was stricken out.

The division shall also encourage cooperative activities by the states to abate water pollution, encourage enactment of uniform laws, encourage compacts between the several states, and collect and disseminate information. Needless to say, these provisions were taken from the Lonergan bill. The consent of Congress is given to states to enter into compacts.

Section 5 provides that any state, municipality or other public body that is discharging untreated or inadequately treated sewage into navigable waters may obtain Federal financial aid in the form of grants-in-aid of loans for construction. Please note they have to be polluters before they can get this assistance. Section 6 extends approximately the same privileges to individuals, provided, of course, that they are discharging injurious sewage or waste. In other words, if a man needs financial aid he must clean out or have already cleaned out all the fish, before he makes his application for a loan.

Section 8, the teeth of the bill, opposed by those who are dumping wastes

into our streams, was eliminated. It would have prohibited certain forms of pollution, and provided the machinery to compel polluters to clean up their mess, and stop contaminating waters that belonged, not to them, but to the public.

The Section 8 in the bill as passed authorized an appropriation of $300,000.00 for each fiscal year beginning July 1, 1938, for all necessary expenses of the Division of Water Pollution Control—investigations, expenses of packing, crating, drayage, and transportation of personal effects of the personnel of government departments on duty with the Public Health Service upon permanent change of station, pay and travel expenses, allowances of reserve engineer officers while on active duty, etc., included.

Section 9 authorizes the appropriation of $700,000.00 for each fiscal year beginning July 1, 1938, to be paid to the states for expenditures to be disbursed by or under the direction of their respective State health authorities in the promotion of investigations, surveys and studies necessary for the prevention and control of water pollution.

Section 10 allows the Secretary of the Treasury to appoint, upon recommendation of the Surgeon General, engineers, attorneys, experts, research assistants, examiners, and consultants, as may be necessary. There are plenty of provisions in the bill to cover all this kind of work, but not one cent of the $1,000,000 a year is actually and directly used to clean up pollution.

There are a lot of definitions, restrictions, and instructions to the Surgeon General, who is the leader and the "Court of Last Resort" in the law. I have outlined only the high spots. Upon the personnel of the Division of Water Pollution Control will depend much of the success or failure of that part of the old Lonergan bill that becomes law.

My last information before leaving Washington was that the President *had not* signed the measure.

Senator Lonergan's statement on the bill as set forth in the Congressional Record of June 9th is well worth reading, and probably expresses the views of a majority of those interested; also the statements of Senators Barkley and Copeland, as set forth in the Record of June 8th, are interesting. There is attached to this statement a copy of the law. These Senators promise future cooperation in further legislation to abate pollution. Perhaps at some future date we may obtain an amendment that will contain some law enforcement provisions.

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THE PRESIDENT: Thank you, Mr. Denmead, for the presentation of the report of the Pollution Committee. This, in my opinion, is one of the most important committees of the Society, and I think that this Committee should be continued for the next year, and will entertain a motion to that effect.

MR. ELMER HIGGINS (Washington, D. C.): I move that the Committee be continued, and include in the motion further instructions from the Society that the Committee be authorized and directed to follow the amendments and corrections and developments that must inevitably be made if this pollution measure is to benefit fish.

May I make the further comment that this pollution bill is not a fish bill, that it will do very little in protecting the fisheries of the country from the evils of pollution. It is primarily a public health measure. I don't condemn it for that. We recognize that public health is above all else the most important consideration, but I do insist that the fisheries interests are not protected by this type of legislation, that the very structure of the administrative agency is not such as will inspire confidence in the success of its work in the direction of fishery protection, that the Board of Control, the engineers, appointed to pass on all pollution treatment works are sanitary engineers from the Public Health Service, and we can not expect any of them to be

directly interested in the conservation of wildlife. I feel that the battle is only started and that this Society must give special attention to the protection of fish. We must not lull ourselves into a feeling of satisfaction or confidence that anything constructive has been done for fish as such, and we need to give it further attention and support.

(The motion was seconded.)

THE PRESIDENT: Of course, that motion carries with it "subject to such alterations as the President-Elect may deem wise and necessary."

(The motion was voted upon and carried.)

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## REPORT OF THE COMMITTEE ON AMERICAN FISH POLICY

E. L. WICKLIFF

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## HISTORY OF THE NORTH AMERICAN FISH POLICY

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During the Sixty-third Annual Meeting (1933) of the American Fisheries Society, President Fred A. Westerman was authorized, by resolution, to appoint a committee to draft an American Game-Fish Policy and to report back at the next annual meeting.

At the 1933 session Mr. Seth Gordon, at that time President of the American Game Association, presented a paper entitled, "Scientific Management—Our Future Fisheries Job," in which he pointed out the need for an American Game-Fish Policy.

On January 22, 1934, the Council of the American Fisheries Society held a joint meeting with the International Association of Game, Fish and Conservation Commissioners at the Pennsylvania Hotel in New York City and sponsored the American Fish Policy in cooperation with International, National and Regional groups.

On January 23, 1934, President Westerman read a paper at the American Game Conference entitled, "An American Fish Policy," in which he pointed out the basic importance of the biological, economic and social phases of our fisheries problems and suggested a more orderly course of fisheries management in the future. He suggested there would be differences of opinion on most points, and at this time your Committee can testify to the accuracy of his statement.

Under date of May 29, 1934, I received a carbon copy of a letter sent by President Westerman to Secretary Gordon announcing the appointment of a committee of fifteen members to draft an American Fish Policy.

A Progress Report was presented to the Society on September 12, 1934, at the Montreal meeting.

At the 1935 Tulsa meeting an outline of the proposed North American Fish Policy was presented, approved by the Society, and printed in the Transactions on pages 27, 28 and 29.

At the 1936 Grand Rapids meeting your Committee presented a 38-page progress report which was accepted by the Society. On March 19, 1937, approximately 700 copies of this revised report were distributed to the membership of the Society, and during the 1937 convention at Mexico City the Executive Committee authorized the selection of a "boiling-down committee" of five members to condense the report.

On September 15, 1937, I sent the Committee a 17-page revision of the proposed Fish Policy. To date suggestions have been received from forty-seven contributors, practically all of whom are members of the American Fisheries Society.

The Policy was reduced from 38 mimeographed pages in 1936 to 17 pages in 1937, and at present it consists of 9½ pages with approximately 6,000 words. The American Game Policy, adopted in 1930, contains 21 printed pages and approximately 11,000 words. I have available 100 copies of the revised draft for distribution to those interested, and hereby submit a copy for the record.

With the above facts before you, and after four years of effort, I move you, Mr. President, the adoption of our North American Fish Policy, and that it be printed in the Transactions of the American Fisheries Society, subject to later revision by the Society.

## NORTH AMERICAN FISH POLICY

### Introduction

It should be recognized by the various governmental agencies directly or indirectly involved in fish management, as well as by the general public:

1. That fish constitute an outstandingly important element in the immensely valuable aquatic resources of North America.
2. That fish furnish the people of the continent with a large source of high-quality food.
3. That commercial and game fishing, directly or indirectly, give employment to many thousands of people, and constitute a prime factor in the support of the populations of large coastwise and interior regions.
4. That recreation centering about fishing provides a vitally important though intangible factor in maintaining social stability in a tense, industrialized age.
5. That fish life has other important values, as in education and research.
6. That the fish resources of the continent have often been regrettably depleted in the wasteful exploitation of our natural resources, and in the despoliation and elimination of many waters.
7. That these depletions of the fish resources lead to serious economic and social losses.
8. That fish are crops, capable of being conserved, restored and increased through sound management practices.

In order to discover, initiate and maintain fish-management practices which will lead to the attainment in abundant measure of the economic and social values dependent thereon, it is of vital importance that a wise fish policy be followed. The statement of such a policy is hereby attempted, in the hope that it may serve as a guide to legislators, conservation commissioners (or boards), and officials, project supervisors, investigators and the interested public; that it will help to avoid the undue waste of energy engendered by official jealousies and conflicting ideas; and that it may focus attention on fundamentals, and lead to effective action.

On all sides there is a most urgent need for effective action to save and restore and build up the fish resources of North America. This Policy aims to point the way toward the attainment of such action. But neither this Policy nor any other is scheduled to bring about a wildlife millenium. There is no easy road, and no substitute for a combination of foresight, intelligence, courage, and uninterrupted activity. There will often be need for drastic revisions in practices.

Fish management is a live and growing field. The best judgment of the day may be far ahead of the practices in many regions, but the practices now current in the most progressive circles are bound to become obsolete within a few years. There will be need for a revision of attitudes as well as practices, and even such general policies as the one here presented will no doubt require extensive revision.

## Fish Policy

I. RELATIONSHIP BETWEEN FEDERAL OR DOMINION AND STATE OR PROVINCIAL GOVERNMENTS WITH RESPECT TO THE ADMINISTRATION, REGULATION, PROPAGATION, DISTRIBUTION, AND INVESTIGATION OF GAME AND COMMERCIAL FISHES AND THE DISSEMINATION OF FISHERIES INFORMATION.

1. *Administration and Regulation.* It is desirable that the administration and regulation of all fisheries should be under the separate states or provinces except where migratory fishes are the common concern of more than one state or province, when the federal government or governments (international waters) should have control. It is apparent that uniformity of local, national, or international fishing laws or regulations is essential for the preservation and the proper utilization of the fisheries resources of many waters. The possibilities of proper control and proper utilization of a fishery or sea resource are often apparent. Outstanding in this regard are the results that have followed the operation of the Pacific Halibut Treaty between Canada and the United States, and the Pelagic Sealing Treaty between the United States, Great Britain, Japan, and the Union of Socialist Soviet Republics. Fishery regulations in general, including uniformity where uniformity is desirable, should be based on proper practical and scientific knowledge. The gathering of such knowledge should be promoted by the administrative agencies and other interests concerned directly or indirectly in the welfare of the fishery involved, and should be undertaken as speedily as may be feasible by the government or governments responsible for the proper utilization and the perpetuation of fisheries resources.
2. *Propagation and Distribution.* The responsible agency (state, provincial, dominion, federal) should formulate the stocking policy, should assume leadership in cooperative undertakings, should receive from all cooperating agencies all applications, requisitions, or plans for stocking fish or other aquatic forms of life to prevent duplication of plantings, should distribute the applications to the cooperating agencies and arrange for exchange of eggs and fish between agencies to reduce the travel and expenses in the distribution of the hatchery output, and should coordinate any other activities of the cooperating agencies wherever duplication of effort can be eliminated and expenses reduced. On international, inter-provincial, interstate, and other waters where joint responsibility exists, an agreement should be reached concerning the stocking policy and rigidly adhered to by the responsible agencies.
3. *Investigations* (*Surveys and Researches*). Federal investigations of the fisheries should emphasize fundamental problems that have the widest geographical application in the scientific administration of the fisheries, whereas state research should emphasize the solution of the many specific problems of local significance. There should at all times be close cooperation in fisheries research between the various states, provinces, and federal governments, and a coordination of research so that all duplication of work may be reduced to a minimum. The following research projects illustrate the types especially suited for federal prosecution:
   a. Biological, statistical, and technical investigations and surveys of the commercial fisheries of boundary waters.
   b. Research on the improvement of commercial fisheries gear and of processing methods, and the development of new fisheries products.
   c. Economic surveys on the grading, marketing, and distribution of fish and fisheries products.
   d. Research on the migratory species of game fish in boundary waters.

e. Research on type waters and the ecology of their game fish for the purpose of formulating broad principles governing the suitability of the various types of waters to particular species of fish.

f. Fundamental research on the causes, control, and prevention of fish diseases.

g. Research on pollution to establish standards of water suitability favorable for fish and other aquatic forms of life.

4. *Exchange of Research Data.* In order to assure close cooperation in fisheries research between the various states, provinces, and federal departments, coordination of research, and the reduction of duplication of research to a minimum, there must be a free exchange of scientific programs and data. A central agency to disseminate information on all phases of fisheries research, fish culture, fisheries management, pollution, etc., should be established, preferably in the U. S. Bureau of Fisheries at Washington, D. C., and in the Dominion Department of Fisheries at Ottawa, Canada. Each state and province should then send to this central agency copies of all published and mimeographed reports on the progress or results of its research, and of any proposed program of research.

II. OBJECTIVES OF FISHERIES ADMINISTRATION AND MANAGEMENT.

1. *Planning Boards and Priority Rights of the Fisheries.* The federal, dominion, state, provincial, and regional planning boards should consider the fishery resources as a very important element of national wealth and not as a minor incident in the development of power, flood control, drainage, irrigation, reclamation, and recreational projects, as has been done in the past. The planning boards should recognize wherever possible the principle of prior right for the fisheries. Only when a proposed water development exceeds in public value the fisheries resource, should the latter be sacrificed, in which case the fishery interests should be compensated fully for their losses. The fisheries should be given equality of representation on all planning agencies at all times and should be represented by qualified persons from the state, provincial, and federal agencies involved.

2. *Public Ownership and Fishing Rights.* Public ownership of lands based on fishing waters, as well as on forestry, game, watershed, parks and recreation, should be recognized as essential to the public welfare in its preservation of public fishing. Lands purchased primarily for public fishing should be made available for other public services not detrimental to fishing. Lands adjacent to waters already held in trust for the public should be used for public fishing when such use is not inconsistent with the purpose for which the lands were purchased and are now held. Any conveyance of title from any public agency to private ownership should contain a reservation of public rights in any fisheries that may be involved. Public rights should be recovered by long-term leases or otherwise when possible in waters or shores that have been appropriated for private or corporate uses and that cannot or should not be purchased. Fishing rights or leases of land should be acquired with the understanding that any improvements or construction work may be carried out to guarantee a maximum return in public fishing. Restrictions or easements by prior owners which would prove detrimental to the development and enjoyment of public fishing waters should be avoided in purchasing or leasing lands or fishing rights.

3. *Personnel Training Facilities.* It should be recognized that successful fisheries administration and management require personnel well trained in the scientific approach and in fact-finding. The study of the fisheries should be developed as a profession equivalent to forestry and agricul-

ture. The facilities for training men in the fisheries are inadequate to meet the present varied requirements. The many divisions and subdivisions of the field and the specific requirements of each must be fully recognized. There must be practical fish-culturists and investigators of fish-cultural problems. Among the latter some will wish training in the special fields of fish pathology, nutrition, breeding, statistical analysis, and fish-cultural mechanics. Provision must be made for practical management of public waters in the interests of sportsmen, commercial fishermen, and the broader conservationists. Many complicated problems are involved here that require the attention of specially trained investigators and administrators. To meet the present situation, as well as to provide for future contingencies, it would seem desirable to encourage:

a. The further development of fisheries work in those institutions of learning which have already initiated such a program.
b. The establishment in our universities of courses in fish culture, fisheries management, and fisheries biology. The more fundamental courses prerequisite thereto are now quite generally included in university curricula.
c. The introduction of short courses a year or two in length in which students may prepare themselves for the more practical phases of fisheries work, and in which practical fisheries workers may become acquainted with the latest discoveries and developments in the field.
d. The development of facilities through which the students of fisheries work may secure practical experience in fish culture, fisheries management, fisheries conservation, etc. Federal, provincial, and state agencies should be induced to give summer employment to fisheries students in hatcheries, on biological surveys, and in stream- and lake-improvement work. Every student in fisheries should serve an apprenticeship in practical operations, and every scientist who expects to enter the field of fisheries investigations should secure the practical point of view by engaging in active fisheries operations.

4. *Political Interference.* The administration of the fisheries resources should be completely divorced from political influence by providing:
   a. Freedom from political pressure in the appointment and direction of the supervisory and other personnel, and the establishment of such tenure of office that will bring security, promotions based on merit of services, and compensation adequate to attract well-qualified officers and other employees.
   b. Authority not subject to political pressure within a department, commission, or other agency, to establish policies, with powers to put those policies into effect.
   c. Public hearings on regulations and other matters affecting the use of fisheries resources, and the power to appeal from local officers' rulings so that a definite opportunity for presenting facts is provided, with a resulting reduction in the necessity and value of political influence.

   The proposals for a non-political commission for the administration of conservation resources, as embodied in the "MODEL LAW" adopted by the International Association of Game, Fish and Conservation Commissioners in September, 1934, are endorsed as the best means of accomplishing the divorcement of fisheries administration and politics in the United States.

5. *Funds.* Since the general public profits by public fishing, both sport and commercial, funds should be appropriated from general taxes to supplement the monies collected through license fees. All monies collected through penalties assessed and seizures made for violations of

the conservation laws should revert to the conservation fund to be used exclusively for conservation activities. Private funds should be solicited for research and education.

6. *Cooperation.* It is essential that the controlling agency maintain close cooperation and collaboration with and between owners of private waters, sportsmen, commercial fishermen, educational institutions, institutes, experiment stations, and the various branches of government in matters that affect fish production, management of fishing waters, and fishing laws.

7. *Education and Publicity.* Since an enlightened public leads to sound conservation laws and the rigorous observance of these laws, every avenue of approach to the public mind should be utilized in making available the most recent authoritative information on conservation matters. Knowledge of the fisheries may be disseminated by means of:
   a. Organized associations and publicity bureaus.
   b. Public addresses and discussions on the platform and through the radio.
   c. Newspaper and magazine articles.
   d. Motion pictures in theatres and elsewhere.
   e. Small pamphlets and leaflets.
   f. Essay contests in schools.
   g. Establishment of courses in conservation based on well-prepared texts written for the schools of various grades.

8. *Fish as Crops.* It should be recognized that fish should be handled as crops, and that our fishing waters, like our farm lands, possess variable potential capacities for production and must be harvested intelligently in order to provide an abundant or satisfactory yield each year. In order to safeguard good fishing from year to year it would be advisable to leave an ample supply of stock or seed in the lakes and streams and not depend entirely on artificial propagation. The factors that control the annual production of fish are not thoroughly understood at the present time and need to be analyzed by more intensive research if the waters are to be utilized to their fullest capacities.

9. *Private Propagation.* The construction of private rearing ponds and hatcheries for commercial purposes should be encouraged. All such enterprises should be regulated under state or provincial license, the fees not to exceed the amount required to pay for inspection, technical advice involving such problems as disease, parasites, mortality, and nutrition, and the overhead charges involved.

   Experimental work should be carried on to determine whether fish and other aquatic forms of life can be raised successfully as crops by farmers, either as part-time or full-time work.

10. *Management of Fishing Waters.* Fish management requires a balanced fisheries program that may involve a careful study or adjustment of any or all of the following factors of production or abundance: legal restrictions, enforcement, propagation, environmental control, introduction of exotic fish, food, predator control, control of disease and parasites, and nurseries and refuges. In addition, intelligent management requires accurate statistics of yield and a good knowledge of the natural history and life history, particularly age, growth and survival data, not only of the game and commercial species of fish but also of the predators or obnoxious and forage fish. Since *soil erosion, reforestation, drainage, flood control, water restoration, and impoundment of waters* are now recognized as tremendously important factors in fish production, the closest contact should be maintained between fisheries officials and the agencies responsible for these various activities.

III. OBJECTIVES OF FISHERIES RESEARCH.

1. *Lake and Stream Surveys and Improvements.* Proper stocking and improvement of our lakes and streams depend upon an adequate survey of these waters. Until the fundamental physical, chemical, biological, and economic factors are determined by qualified fishery biologists, a sound basis for fish plantings and environmental improvements, as well as other phases of fisheries management, is lacking. It may well be made a cardinal principle in the management of any waters to assume that until fish-cultural and fish-betterment procedures have been definitely shown by accurate and adequate data to be effective, they should be regarded as of doubtful value.

The surveys should include:

a. A rapid, comprehensive inventory of all of the fishing waters in the state or province, preferably by watersheds.
b. Intensive studies over a period of years of a number of lakes and streams representative of the waters in the state or province.

The main purpose of a general survey is to answer the following questions about each lake and stream:

a. What species will most likely find conditions suitable for maintenance, growth, and reproduction?
b. Is the water in need of stocking in order to utilize fully the food resources and maintain the densest population consistent with normal growth and maximum productivity?
c. What size fish should be planted in the expectation of giving the desired results?
d. What, if anything, aside from restocking should be done to make the stream or lake more productive?

Intensive, long-time research on type waters is necessary in order to apply fully the data collected in the general survey and to indicate desirable changes in the preliminary management plans as outlined for each water. However, it is recognized that each lake and stream constitutes an individual problem to which the results of type studies cannot always be applied without modification.

Improving the environment for fish in our lakes and streams is now a recognized phase of fishery management. The purpose should be to alter these waters so that they will support more fish and furnish more fishing. The major stipulations that should be followed in all lake and stream improvement work are:

a. An adequate survey should be made to determine the abundance of fish and the factors that limit fish production.
b. A plan for improvement should be prepared by a fisheries biologist with experience in construction work or with engineering advice.
c. The installation of devices or other alterations of the environment should be done under the direct or advisory supervision of this fisheries biologist.
d. Checks of the work should be made annually if possible to determine its biological value and to effect necessary repairs and alterations in the structures.

The biological phase of improvement work should receive consideration equal to, if not greater than, the engineering. Well-constructed devices may effect no improvement; poorly-built structures, though they may be biologically efficient, are temporary. Of primary importance is the retention of natural appearances. Where a choice exists between some artificiality and poor fishing, the former is preferable.

2. *Fishways and Screens.* With the recent development of gigantic flood-

control and extensive water-restoration projects, the problem of fish migration has received new impetus and added significance which justifies a considerable expansion of the present research facilities to provide more effective, practical fishways and screens.

3. *Statistics.*
   a. *Sport Fisheries.* Inventories should be made of the abundance and kind of fish available to the angler and of the catch and kind of fish taken annually by the fishermen. Special attention should be given to a determination of the abundance and kind of fish in type waters. Total annual yield of type waters should be obtained by an intensive creel census, preferably over a period of years. This census should be taken by trained individuals to assure accuracy and completeness, should be taken every day of the fishing season, and should include all of the fishing on the waters studied. In addition to the intensive census on type waters, a general census representing a random sampling should be taken over the entire state or province or district, to determine the nature of the fishing and especially the trend of the catch from year to year. The use of uniform methods of taking the census and in compiling the data should be encouraged to permit comparison of the information gathered in various areas by various agencies. A study might well be made of the preferences of the anglers with respect to species of fish by the use of questionnaires or of a stub attached to the fishing license.
   b. *Commercial Fisheries.* The statistics of the production of commercial fisheries may offer some clue to the abundance of the stock, but cannot provide a precise measure of abundance. Abundance can be determined accurately only in terms of production in relation to fishing effort, that is, production per unit of effort. The statistics of the commercial fisheries should therefore include complete data on the fishing effort that led to the production of the recorded catch. Continued attention should be given to the development of satisfactory methods for the analysis of commercial fisheries statistics.
4. *Improvements in Fish-cultural Methods.* It is believed that improvements in fish cultural methods, including such items as nutrition, selective breeding, and disease control, are greatly needed and are most likely to result from experimental studies directed and conducted by persons specially trained in research methods, in fact, by those who know how to conduct experiments by approved methods and who are well enough informed to interpret and evaluate results correctly. If experimental results are to have any value in fish-cultural practice, they must also be interpreted to fish-culturists who in turn must be able to apply them to large-scale operations. The investigator is trained to experiment and to interpret results. The fish-culturist is trained in the work of producing fish. Both are specialists in their respective fields, but each is dependent upon the other in the achievement of the original objective. Consequently, closer cooperation and collaboration between these two groups than past history reveals is necessary. The ideal arrangement would seem to be a Fish-cultural Experiment Station having a research staff for developing and testing new ideas and an operating staff of fish-culturists for putting them into practice. The research staff would be provided with laboratory facilities for conducting research in all fields embracing fish culture, including pathology, disease control, nutrition, genetics, and selective breeding. The fish-culturists would have hatchery and pond facilities for fairly large-scale operations with both cold- and warm-water fishes.
5. *Stocking Policies and Standards.* Stocking policies should be determined to a large extent by surveys as discussed under Section III, Sub-

section 1. These policies should be modified from time to time in accordance with the results of:

a. Intensive studies of type waters.
b. Observations on the results of management and of catch in individual waters.

The stocking policy for each lake or stream should specify:

a. Species of fish which should be introduced or encouraged by artificial plantings.
b. Approximate number of fish required (as near as can be determined) to maintain maximum fishing consistent with food supply and fishing intensity.
c. Proper size or age of fish to be planted to produce best results.
d. Parts of each lake or stream best adapted to receive the plantings.
e. Proper time of year for plantings.
f. Local improvements or regulations needed to protect adequately the fish planted.

Unless investigations should suggest otherwise, the following standards should be adhered to:

a. No introductions of exotic species of fish should be made in the waters that now contain only native species which provide good fishing.
b. Plantings of exotics should be made or continued in barren waters, in waters where no game fish are found, and in waters where exotic species are best suited to the environment and have proven to be of higher value for fishing purposes than native species. In all other waters the native species should be encouraged.
c. Planting should be discontinued in waters where the introduction of exotic species threatens extinction of the native species in an entire area, and every effort should be made to restore the native species to its normal status.
d. The number of any species of native non-game fish should not be reduced unless such reduction is in the interest of better fishing.
e. No effort should be made to introduce exotic fish merely for the purpose of increasing the variety of game fish.
f. All stocking should be planned with adequate consideration of possible effects on contiguous waters within the possible limits of migration of the planted fish. Plantings in private waters which may affect public waters should be rigidly controlled.
g. The allocation to and actual planting of fish by a well-trained personnel familiar with individual stream and lake requirements should replace the "application system" to eliminate unwise and wasteful plantings, overstocking in locally favored waters, and the neglect of other waters not so favored.
h. Fish produced by public funds should be distributed to waters open to public fishing only, leaving the stocking of private waters to private enterprise.
i. Only sound and healthy fish should be planted in public or private waters to prevent the danger of spreading diseases and parasites.
j. Accurate records of the number, length and weight of each species planted each year and of the exact points or sections planted should be kept for each lake and stream. These records should be kept in the permanent files of the hatchery and of the department concerned.

Even though the above standards relative to the introduction of exotic species of fish are acceptable, the "foreign fish" problem still requires much more study. The possible advantage of utilizing stock from adjacent waters rather than from distant regions, the effect on the native game fish of the introduction of a new and hardy stock, and the feasibility of introducing new forage fish into a lake or stream are

some problems that may be studied with profit. It would also be extremely valuable in guiding the present and future fish-cultural activities if all of the available information on the successful and unsuccessful introductions of fish could be compiled, with the data arranged by species to show clearly the failures, successes, advantages, and disadvantages of each introduction. Such compilation could probably be done best by a special committee appointed by the President of the American Fisheries Society.

6. *Natural and Artificial Propagation.* The relative values of natural and artificial propagation should be determined for each major species of fish in various types of waters. This most fundamental of all fisheries problems presents the greatest challenge that confronts the fisheries scientist and the conscientious fish-culturist. Upon its solution, which has already been delayed far too long, rests the future direction of our fish-cultural activities. Considerable evidence has already appeared which indicates the relative insignificance and futility of artificial propagation of certain commercial species. It is therefore imperative that a greatly expanded research be concentrated on this problem at once.

7. *Nurseries and Refuges.* Whether, where, when, and how nurseries and refuges should be established are questions that cannot be answered definitely for all regions. More research is needed to determine the most efficient and economic types of nurseries (hatchery ponds, field stations) to be used under varying conditions. Investigations should also determine when refuges should be established to protect spawning fish, young and immature fish as in feeder streams, or an entire population in a lake or in sections of a stream.

8. *Life and Natural Histories.* It is obvious that in order to manage intelligently any crop of fish, the habits, reactions, growth rate, spawning age, etc., of the fish must be known. Since the life history of a species may vary considerably with the different waters, every opportunity should be employed to obtain at least the more critical data for every important lake and stream.

9. *Predator Control.* Practical observations and scientific research have demonstrated the necessity for the control of fish predators in the immediate vicinity of hatcheries and rearing stations. Research is needed to provide practical methods of driving off predators, particularly birds, and to prevent predation by means other than the killing of predators. Need for the control of fish predators (mammals, birds, reptiles, and fish) in public waters depends largely upon local conditions; and control is justified only when scientific research has demonstrated that actual damage to desirable fish populations is occurring. The indiscriminate, wholesale slaughter of fish-eating birds should not be permitted.

Further research should be carried out on the management of the beaver, which, although not a predator, may cause unfavorable conditions for fish life and require control in certain waters. Research is particularly imperative in determining the actual damage that is done to fish in lakes and streams by the so-called noxious fishes (gar pike, bowfin, carp). It is recognized that under certain conditions and at certain seasons of the year some control may be necessary. It is not generally recognized, at least in practice, that under some conditions fish predators may be harmless or actually beneficial by preventing overpopulation of the less desirable species or even of the desirable fish and that predators may be a very essential factor not only in maintaining the balance of nature but also in preventing the stunting of growth of the desirable species of fish. The possibility should not be overlooked that in some

cases at least the fish taken by predators are the weak and diseased individuals and that their removal benefits the stock.

10. *Parasites and Diseases.* Notwithstanding the high quality and the increase in the amount of work undertaken by students of fish diseases during the past fifteen years, there is still need for additional effort in this field. Fish-culturists continue to be handicapped by abnormal losses of fish for want of specific and reliable information as to their prevention. Variation in the quality of the water, in the condition of the fish, and in numerous other factors often upsets calculations and renders useless our most cherished procedures. To the end that we may have a more definite knowledge concerning fish diseases and more reliable methods of control applicable to all hatcheries, we urge:
    a. A greater interest among specialists of our universities and governmental services in the study of fish diseases and methods of their elimination.
    b. A closer and more sympathetic relationship between the fish-culturist and the researcher such as is evidenced by the recently established "disease service" in the U. S. Bureau of Fisheries.
    c. A closer cooperation between state or provincial conservation departments and research institutions, especially state universities.
    d. A more concentrated study on the control and prevention of the most destructive diseases in our hatcheries, such as furunculosis.
    e. A re-examination of our methods of disease control by a group made up of experienced fish-culturists and fish-pathologists, and the preparation of a series of tests by this group in various hatcheries for the purpose of standardizing the methods.
11. *Forage Fishes.* It is recognized that forage fishes may constitute an extremely important factor in the success of fishing waters and that the tendency in the past has been to permit their partial extermination in many of our inland waters by bait dealers and fishermen. To remedy the situation the following recommendations are made:
    a. That state and provincial departments regulate more strictly than in the past the capture and sale of bait minnows.
    b. That more studies on the life history, habits, food, reproduction, enemies, etc., of forage fishes be encouraged.
    c. That investigations be conducted relative to the propagation, methods of holding, and the control of diseases of our forage fishes for the purpose of developing a reliable cultural procedure.
    d. That suitable forage minnows be propagated by state and provincial hatcheries for distribution in depleted waters.
12. *Mussels, Oysters, Sponges, and Other Non-fish Water Resources.* It is recognized that the waters produce valuable products other than fish and that many of these have received very scant attention from conservation administrators and scientific investigators. It is believed that greater recognition than is accorded at present should be given the conservation of at least some of these non-fish water products by a study of their abundance, life history, habits, culture, protection, etc.
13. *Commercial Fisheries Gear and Products.* The experimental study of the action of the various types of commercial fishing gear on the various species of fish, and the reaction of these fish to the various types of gear, is an important research objective. Commercial fishing is probably the only factor involved in the abundance of the food fishes that can be placed under the immediate control of man. The oceans, the Great Lakes, and the large interior lakes of Canada, the principal sources of our food fishes, are too large to be subjected to environmental control. The effectiveness of artificial propagation is still a

subject for debate. Since the balance between mortality and replacement must be controlled largely by the regulation of fishing operations or gear, it is very important that many more data be collected on the selectivity of fishing gear so that the production can be controlled intelligently without undue hardship to the fishing industry and to the fishermen. Recent experiments with various types of nets on the Great Lakes and on the Atlantic Ocean have shown conclusively that by the introduction of certain modifications in the building of nets much can be done to reduce the wastage and destruction of immature or small fish.

More research should be carried on to improve and prolong the life of the materials used in the building of fishing gear and thus save the industry thousands of dollars each year. Greater progress should be demanded also in the investigation of the grading, marketing, and distribution of fish and fisheries products and in the development of new products and processing methods.

14. *Publications.* With the rapid expansion of fisheries research there has developed urgent need for additional facilities and funds for the prompt publication of the results of investigations. The value of many excellent and costly researches and surveys has been lost and duplication of effort has resulted because "funds were not available for publication."

IV. ESSENTIALS OF A POLLUTION POLICY.

All efforts to propagate fish and develop other aquatic resources necessitate water unaffected by destructive pollution. Pollution control should include the headwaters and tributary waters to cover the stream drainage as a whole and not be limited to lower waters and large sources of contamination. The elimination of pollution becomes a primary necessity in any fisheries program. Adequate pollution control requires:

1. A legal basis for pollution control considering all water resources.
2. A recognition of biological values in water resources as well as public health and industrial, municipal and property values.
3. Technical information with reference to the effects of pollution on the fisheries, as well as on public health, as a basis for control action. This necessitates thorough studies by qualified fisheries biologists as of equal importance with investigations from the standpoint of public health.
4. A coordination of federal or dominion interests, as having jurisdiction over coastal, navigable, and interstate or inter-provincial waters, with those of states, provinces, and individuals.
5. Continued research on the effect of pollution, methods of elimination of pollution, and methods of treatment and utilization of waste products; to be followed by demonstrations of methods determined by such research.
6. The development of a public understanding of the scope, importance, and necessity for pollution control to accomplish stream and lake sanitation, to permit the growth of desirable fish, and to enhance property values.

V. DISCRETIONARY POWERS.

Many states have incorporated in their conservation laws a provision that gives those commissioners or directors who are charged with the duties of protecting fish, birds, game, and other wildlife the power to regulate the time and manner of taking fish and game. It is believed that in the best interest of conservation such discretionary power should be vested in the conservation commissioners or directors of every state and province, and of the federal bureaus charged with the enforcement of federal laws, and should be made applicable to both sport and commercial fisheries. In some states the commercial fisheries have been specifically exempted from the

application of the discretionary power act. Nevertheless, effective management of the commercial fisheries requires the same elasticity in regulation that is necessary in any sound conservation program for game fish. Any discretionary power granted to govern the commercial fisheries should, however, be so circumscribed as to safeguard the fishing industry from any violent upsets or radical measures. The immediate effects of any regulation on the industry must always be given careful consideration.

VI. STANDARDIZATION OF COMMON NAMES OF FISHES.

The importance of standardizing the common names of fishes is reflected in the action of the American Fisheries Society in establishing in 1932 a special committee to prepare for adoption an official list of standard common names to correspond to the accepted scientific names. The policy adopted by the committee and published on page 27 of the 1935 Transactions (Volume 65) needs no further elaboration here.

VII. COMPILATION AND SUMMARIZATION OF FISHERIES DATA.

Sub-committees should be appointed by the President of the American Fisheries Society to correlate and summarize at irregular intervals the most recent data and information on various fisheries and pollution problems and to outline methods of research.

NORTH AMERICAN FISH POLICY COMMITTEE

E. L. Wickliff, *Chairman*, Ohio

J. D. Chalk, North Carolina
H. S. Davis, Washington, D. C.
George C. Embody, New York
Fred J. Foster, Washington
Charles A. French, Pennsylvania
Seth Gordon, Pennsylvania
Wm. J. K. Harkness, Ontario
A. S. Hazzard, Michigan
Carl L. Hubbs, Michigan
A. G. Huntsman, Canada
S. B. Locke, Illinois
James A. Rodd, Canada
John Van Oosten, Michigan
Geo. C. Warren, Jr., New Jersey

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THE PRESIDENT: Thank you, Mr. Wickliff, and your boiling-down committee, for your fine contribution to the Society. Your motion to adopt the Policy subject to the revision of the Society, if met with a second, will be put to the Society.

MR. B. M. BRENNAN: I would like to second Mr. Wickliff's motion.

THE PRESIDENT: Is there any question concerning the motion to adopt the report? If not, all in favor say "aye." Contrary, "no." The motion is carried.

THE SECRETARY: One of the questions that comes up at this particular time is whether it is desirable to continue the Committee. My own feeling, Mr. President and members, is that it might be wise to continue the Committee, at least for another year or two, because there may develop a need for further revision of certain phases of the Policy. We did that when the American Game Policy was adopted in 1930. We continued that Committee as a part of the Game Conference for several years after the policy it formulated was actually adopted, in order that that Committee might take charge of the job of bringing in suggested revisions. The way it worked out was that it was largely the committee's duty to call attention to the progress that had been made in applying the policy, rather than bringing in amendments to it.

THE PRESIDENT: The President will entertain a motion to continue the Fish Policy Committee. I think we can do that only for another year at this time. What is the pleasure of the Society?

THE SECRETARY: Subject to such alterations as the President-Elect and the Chairman may agree upon.

THE PRESIDENT: I think that is understood—subject to any alterations that the Nominating Committee may see fit to make.

MR. P. J. HOFFMASTER (Michigan): I move you that the Committee be continued for one year.

MR. FRED J. FOSTER (Washington): I second the motion.
(The motion was voted upon and carried.)

DR. H. J. DEASON: Before we proceed I believe the Society should express its appreciation to Mr. Wickliff and to the members of his Committee for the excellent work they have done in preparing this American Fish Policy for us.
(The motion was seconded, voted upon, and unanimously carried.)

THE PRESIDENT: Again, thank you, Mr. Wickliff, and your associates, for your work.

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### APPOINTMENT OF COMMITTEES

*Auditing*—A. D. Aldrich, Oklahoma, *Chairman;* Albert Powell, Maryland; P. J. Hoffmaster, Michigan.

*Resolutions*—Herbert C. Davis, California, *Chairman;* Charles E. Jackson, Washington, D. C.; V. M. Simmons, Indiana; H. H. MacKay, Ontario, Canada; E. L. Wickliff, Ohio.

*Nominations*—P. J. Hoffmaster, Michigan, *Chairman;* Eugene W. Surber, West Virginia; H. S. Davis, Washington, D. C.; H. S. Swingle, Alabama; Charles O. Hayford, New Jersey.

*Time and Place*—B. M. Brennan, Washington, *Chairman;* James Brown, Kentucky; John W. Scott, Wyoming; Russell Hunter, Vermont; James A. Rodd, Ottawa, Canada.

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*Publications*—Following the 68th Annual Meeting, President-Elect Foster appointed Dr. Ralph Hile, Ann Arbor, Mich., to the Committee on Publications for a term of five years, to succeed Dr. John R. Greeley, Albany, N. Y., whose term had expired. Doctor Van Oosten was persuaded to accept the chairmanship of the Committee for another year, which now consists of the following:

| *Committee* | *Term Expires** |
|---|---|
| Dr. Ralph Hile, Ann Arbor, Mich. | 1943 |
| Dr. Lauren R. Donaldson, Seattle, Wash. | 1942 |
| Dr. Paul R. Needham, Palo Alto, Calif. | 1941 |
| Dr. John Van Oosten, *Chairman,* Ann Arbor, Mich. | 1940 |
| Prof. W. J. K. Harkness, Toronto, Canada | 1939 |

# REPORTS OF COMMITTEES

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### AUDITING COMMITTEE

MR. A. D. ALDRICH: Your Auditing Committee has checked the books of the Society, also the supporting vouchers, for the period July 1, 1937, to June 15, 1938, and finds the report as submitted to be correct. This Committee recommends that the appropriation for clerical and stenographic services for the fiscal

*Indicates the annual meeting at which the term of each member of the Committee will expire.

year 1938-39, exclusive of expenses incident to the preparation, proof-reading and indexing of the transactions of this meeting, be the same as heretofore, namely $350.00.

(The motion to adopt the report was seconded, voted upon and carried.)

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## COMMITTEE ON RESOLUTIONS

MR. H. C. DAVIS: Your Resolutions Committee met and worked diligently, and has several resolutions which it recommends for adoption by the Society:

### *1. Great Lakes Fisheries—International Board of Inquiry*

WHEREAS, At a conference held on February 25, 1938, at Detroit, Michigan, the Council of State Governments adopted a resolution declaring that

> "WHEREAS, The continued decline of the Great Lakes fisheries seriously threatens vital economic interests in a wide area adjacent to the Lakes and occasions social and economic distress to a large number of our citizens who earn their livelihood in the fishing industry; and
>
> "WHEREAS, Past efforts by the several states to prevent exploitation by regulating the taking of food fishes have been without avail;
>
> "BE IT RESOLVED, That this conference urges the appropriate agencies of the Federal Government of the United States to discuss with the appropriate Canadian authorities, without delay, the advisability of a treaty to establish an International Board of Inquiry, whose function it shall be to consider and to recommend measures for the conservation of the Great Lakes fisheries—and that this conference recommends such a treaty.
>
> "BE IT FURTHER RESOLVED, That in the meantime the states be urged to take vigorous action, individually and in cooperation with one another, to conserve the fisheries; . . . ."

WHEREAS, This resolution confirms substantially those resolutions of a similar nature adopted by the American Fisheries Society at its annual meeting in 1936, and at many other previous meetings, including those held in the years 1891, 1896, 1905, 1906, 1907, 1908, 1918, 1924, 1926, 1927, 1928, 1929, 1931, and 1933; now

THEREFORE, BE IT RESOLVED, That the American Fisheries Society, in convention assembled at Asheville, North Carolina, on June 24, 1938, reaffirms its stand on this important conservation question and expresses its wholehearted support of the action taken by the Council of State Governments; and

BE IT FURTHER RESOLVED, That a copy of this resolution be submitted to the President of the United States, to the Secretary of State, to each United States Senator of the States fronting on the Great Lakes, to the United States Commissioner of Fisheries, and to the Executive Director of the Council of State Governments.

(Upon motion, duly seconded, the resolution was voted upon and adopted.)

### *2. The Federal Water Pollution Act*

WHEREAS, The Federal Water Pollution Act recently passed by Congress omitted the necessary enforcement feature and other sections of the original pollution bill previously endorsed by this Society which we believe essential for cleaning up pollution and preventing unnecessary destruction of fish and other aquatic life;

THEREFORE BE IT RESOLVED, That the American Fisheries Society, assembled at Asheville, North Carolina, on June 24, 1938, goes on record as favoring amendments to the Federal Water Pollution Act at the next session of Congress, which will provide the necessary regulations to compel polluters to clean up their pollution when found necessary for the preservation of fish and other aquatic life in navigable waters.

(Upon motion, duly seconded, the resolution was voted upon and adopted.)

### *3. Senate Wildlife Resources Committee*

WHEREAS, The problems incident to the management of our fisheries are many

and complex, and frequently a single body of water involves more than one state; now

Therefore, Be It Resolved, That the American Fisheries Society, whose membership includes officials of the federal and state conservation agencies, and scientists of note from the educational institutions of these United States, urges that there be created in the United States Senate a standing Committee on the Conservation of Wildlife Resources; and

Be It Further Resolved, That a copy of this resolution be sent to the President of the Senate, and to the majority and minority leaders of the United States Senate immediately upon the convening of the next Congress.

Done in convention assembled at Asheville, North Carolina, on the 24th day of June, 1938.

(Upon motion, duly seconded, the resolution was voted upon and adopted.)

### *4. The Late Lester Smith*

Whereas, Conservation and our membership have lost a friend and ardent worker in the passing of Lester Smith, Divisional Vice-president of this Society; now

Therefore, Be It Resolved, That the American Fisheries Society in 68th Annual Conference held at Asheville, North Carolina, this the 24th day of June, 1938, deeply feels his loss and hereby expresses its sincere sympathy to his bereaved family; and

Be It Further Resolved, That a copy of this resolution be forwarded by our Secretary to the family of our deceased friend.

(Upon motion, duly seconded, the resolution was adopted with a unanimous silent rising vote.)

### *5. Appreciation of Courtesies*

Whereas, The meeting of the American Fisheries Society is closing its 68th Annual Conference; and

Whereas, The Society is indebted to the State of North Carolina, to the City of Asheville, to the Governor of the State of North Carolina, to the Director and members of the Board of Conservation, and most particularly to the Honorable John D. Chalk, Commissioner, Division of Game and Inland Fisheries; now

Therefore, Be It Resolved, That the American Fisheries Society assembled in Asheville, North Carolina, this the 24th day of June, 1938, does hereby express its appreciation for the courtesy and hospitality extended to it during our much too short visit in the "Land of the Sky."

(Upon motion, duly seconded, the resolution was unanimously adopted.)

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### *Special Resolution (Adopted early in the meeting)*

The President: A few days ago the International Association adopted by unanimous vote a resolution to be sent to the President of the United States, urging him to sign S. 2857, which is the bill that has been recently unanimously passed by both Houses of Congress just prior to its adjournment. This bill has to do with the five-year fisheries building program. I am wondering if this is not urgent enough for us to take up at this time the proposition as to whether or not the American Fisheries Society should send a telegram to the President this morning, urging him to sign this bill. What is the pleasure of the Society?

Mr. D. N. Graves: I move you that the Secretary be instructed to prepare and send immediately a telegram to President Roosevelt advising him of the wishes of the American Fisheries Society that he sign this five-year building program bill that appropriates funds, as I understand, for a five-year building program for the U. S. Bureau of Fisheries.

THE PRESIDENT: What is the pleasure of the Society?
(The motion was seconded.)

THE PRESIDENT: All who are in favor of this motion signify by saying "aye." Opposed, "no." The Secretary is instructed to send forthwith a telegram to the President of the United States, urging him, at the request of the Society, to sign this bill.

## COMMITTEE ON TIME AND PLACE

MR. J. D. CHALK: As Chairman of the Joint Committee on Time and Place, I beg to report that your Committee unanimously designated San Francisco, California, as the meeting place for the 1939 Convention. Many invitations were received from other cities in the United States and Canada, and it is the regret of the Committee that we could not choose more than one place.

In order to carry out the usual custom of rotation the Pacific Coast seemed entitled to the 1939 Convention, since the meeting had not been on the Pacific Coast since 1928, when it was at Seattle.

The time for the Convention was not determined by your Committee but was left open for final decision by the officers and the executive committees of the two associations.

THE PRESIDENT: In that connection I wish to announce that there will be a joint meeting of the officials and the two executive committees of the two organizations at a luncheon in the ballroom immediately following this session, where a decision may be reached on the time for the 1939 Convention.

MR. H. C. DAVIS: I move the adoption of the report.

DR. J. VAN OOSTEN: I second the motion.
(The motion was voted upon and carried.)

At the conference of the officers and executive committees of the American Fisheries Society and the International Association of Game, Fish and Conservation Commissioners, immediately following the close of the business sessions of the Society, it was agreed (1) that June 26 and 27, 1939, shall be the dates for the 69th Annual Meeting of the Society, with a joint meeting on the evening of June 27 for members of both organizations to discuss policies and plans for future meetings; (2) that June 28 shall be devoted to conferences with Federal agencies, and the evening to the joint annual banquet; and (3) that June 29 and 30 shall be the dates for the 33rd Annual Convention of the International Association, with July 1 reserved for further conferences with Federal agencies if desired. (Later by correspondence with the Chief of the U. S. Biological Survey and the U. S. Commissioner of Fisheries it was agreed that the time on Wednesday, June 28, shall be equally divided between the two Federal agencies to avoid the necessity for holding conferences on Saturday, July 1.—EDITOR.)

## COMMITTEE ON NOMINATIONS

MR. CHARLES HAYFORD: Mr. Hoffmaster, on account of having to leave, asked me to make his report, which is as follows:

The Nominating Committee of the American Fisheries Society has met and nominated the following persons: *Officers: President*—Fred J. Foster, Seattle, Wash.; *First Vice-President*—T. H. Langlois, Put-in-Bay, Ohio; *Second Vice-President*—James Brown, Frankfort, Ky.; *Secretary-Treasurer*—Seth Gordon, Harrisburg, Pa.; *Librarian*—Kenneth E. Cobb, Windsor Locks, Conn.

*Vice-Presidents of Divisions: Fish Culture*—H. H. MacKay, Toronto, Canada; *Aquatic Biology and Physics*—Lauren R. Donaldson, Seattle, Wash.; *Commercial*

*Fishing*—H. J. Deason, Ann Arbor, Mich.; *Protection and Legislation*—William C. Adams, Albany, N. Y.; *Angling*—C. R. Gutermuth, Indianapolis, Ind.

*Committee on Foreign Relations*—Charles E. Jackson, *Chairman*, Washington, D. C.; William J. Tucker, Austin, Texas; John Van Oosten, Ann Arbor, Mich.; Señor Juan Zinser, Mexico City, Mexico; B. M. Brennan, Seattle, Wash.; Russell P. Hunter, Montpelier, Vt.; James A. Rodd, Ottawa, Canada.

*Committee on the Common and Scientific Names of Fishes*—Walter H. Chute, *Chairman*, Chicago, Ill.; Carl L. Hubbs, Ann Arbor, Mich.; William J. K. Harkness, Toronto, Canada; Samuel F. Hildebrand, Washington, D. C.; A. H. Leim, St. Andrews, N. B., Canada; George S. Myers, Stanford University, Calif.; Leonard P. Schultz, Washington, D. C.

THE PRESIDENT: What is the pleasure of the Society?

MR. H. C. DAVIS: I move that the report of the Committee be accepted.

(The motion was seconded, voted upon and carried.)

THE PRESIDENT: Then do you move that the Secretary be instructed to cast a unanimous vote for the gentlemen whose names have been presented for the official staff of the Society?

MR. DAVIS: If there are no further nominations, Mr. President, I move that the Secretary cast a unanimous ballot.

(The motion was seconded, voted upon, and carried.)

THE SECRETARY: The Secretary reports having cast a unanimous ballot for the nominees.

THE PRESIDENT: I am going to ask Walter Chute and Bill Adams to escort Fred Foster to the front.

I want to express to the membership of the Society, and especially the Secretary-Treasurer, my appreciation for the fine cooperation that has been given your retiring President.

Are you ready to receive the new President?

(Those in attendance arose and applauded.)

It is with great pleasure that I present Fred Foster, of Seattle, Washington, the new President of the American Fisheries Society for the ensuing term.

THE PRESIDENT-ELECT: It is needless to say that it is with great pleasure and extreme humility that I accept this office. It has been something that I have valued and looked forward to for many years. I sincerely trust that you may all give me your most hearty support. I am very grateful to the Nominating Committee for the officers they have selected to serve with me, and I shall support this Society as I have in the past.

The younger men, as mentioned by several here this afternoon, are going to take over the Society in a very few years, despite Bill Adams and some of the rest of us, and there is nothing which pleases me more than to see the high caliber of the younger men who are entering the fisheries work and taking an active interest in this Society.

California usually amply advertises itself. In fact, it is unique to find someone else who, without remuneration of any kind, steps forward to champion California. However, in this instance I am going to do so. I think that with the possible exception of Seattle, San Francisco is the most desirable city in the United States in which to hold a convention. You will find the weather delightful, even at this long-range forecast, and no doubt the attraction of the Fair will assist us in obtaining a good attendance at at least part of the meetings.

I do wish to impress upon you the desirability of coming early and staying late to visit the Fair, so that you may give the attendance at the meetings your serious thought. I sincerely hope that we shall have as constructive, as pleasant, and as profitable a meeting as we have had here in Asheville this year.

Is there any further business to come before this convention? If not, we stand adjourned!

(The Annual Meeting adjourned at 1:10 o'clock p.m.)

## In Memoriam

W. H. Behney, Burlington, Vermont

Louis D. Dennig, St. Louis, Missouri

Edwin C. Kent, New York, New York

Dr. K. Kishinouye, Tokyo, Japan

Lester Smith, Port Washington, Wisconsin

Dr. Charles K. Stillman, Mystic, Connecticut

William W. Trimpi, South Orange, New Jersey

## In Memoriam

[illegible] H. [illegible], [illegible]

[illegible] M. Dunning, [illegible]

[illegible] C. [illegible], New York, New York

[illegible] Richardson, [illegible]

[illegible] Smith, [illegible], Wisconsin

[illegible] Charles B. Sullivan, [illegible], Minnesota

William W. [illegible], [illegible]

# PART II
# PAPERS AND DISCUSSIONS

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# PROGRESS REPORT OF THE FISHERIES INVESTIGATIONS OF THE TENNESSEE VALLEY AUTHORITY

ALVIN R. CAHN

*Chief Biological Readjustment Division, Department of Forestry Relations, Tennessee Valley Authority, Norris, Tennessee*

Nearly two years ago I presented a summary of the fisheries program as contemplated by the Tennessee Valley Authority to be undertaken in the valley of the Tennessee River. I feel it incumbent upon me to report periodically concerning the progress which we are making along the several lines of our endeavor, and I know of no opportunity more adequate for this purpose than that afforded by the annual meeting of the American Fisheries Society, because here, before me in a body, are representatives of the active fisheries interests—federal, state, commercial, private, scientific—of the country. You represent those who should be most interested in our work, and I deem it a privilege to report thus to you. Since the last meeting of the American Fisheries Society, the Biological Readjustment Division of the T.V.A. has made some noteworthy advances along all fronts, and I believe that some real progress has been made; however, I leave it to you gentlemen to judge.

I would first report to you a very important step taken during the past winter when the T.V.A. entered into an active cooperative agreement with the U. S. Bureau of Fisheries and with the Conservation Commissions of the states of Alabama and Tennessee (which two states are at least territorially mostly concerned with the Authority's activities in the Valley), through which agreement the Bureau of Fisheries, the T.V.A. and the states concerned cooperate in the attack upon the fisheries problems of the Valley. Thus, the Bureau of Fisheries not only functions in an advisory capacity to us, but enters into active investigation through its personnel, as well as cooperating by managing the production of fish hatcheries constructed by the Authority. The states themselves assume various responsibilities in connection with the fisheries work, such as the transportation of fry, protection, and active cooperation along lines of what we might call the "practical" fisheries. Thus, the facilities of the Bureau of Fisheries, the Authority, the states and local organizations are brought to bear upon the problems involved, avoiding duplication of expense, equipment, and energy, and obliterating any possibility of either overlap of function or conflict of effort. The wildlife problems are not solely the interest and responsibility of the Authority, but a mutual responsibility of all interested parties. I would add parenthetically and for your further enlightenment, that similar agreements have been entered into between the Biological Survey, the Authority, and the above mentioned states in the in-

terest of game problems. I believe you will agree with me that such cooperative arrangements constitute a new procedure in fisheries conservation and one which approaches a logical method of attack upon conservation problems.

Construction operations along various lines have proceeded steadily. Two additional permanent-level rearing ponds have been constructed on the Norris Reservoir, bringing the total to five in that reservoir alone. We are now starting the construction of a permanent-level rearing pond on the Chickamauga Reservoir, which will function in connection with the fish hatchery now being erected in northern Alabama. What is undoubtedly the largest constructive operation which the Authority has undertaken in the interests of fisheries conservation has been begun on the Elk River in Limestone

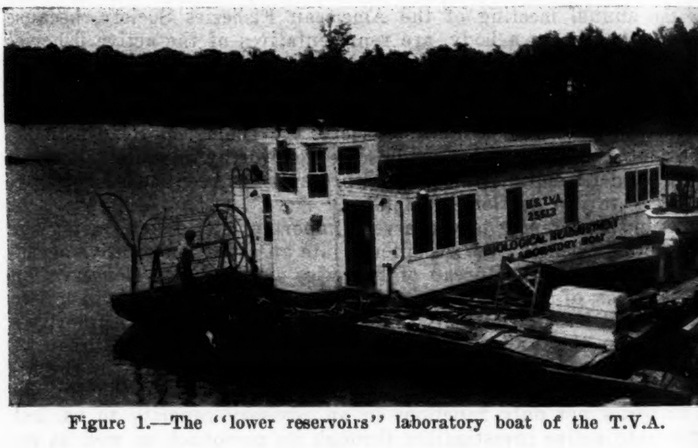

Figure 1.—The "lower reservoirs" laboratory boat of the T.V.A.

County, Alabama. Here work is under full sway on the construction of a fish hatchery which will include 77 ponds and 111 acres of water surface. It is believed that this hatchery can be completed in approximately two years. Upon completion it will be operated by the U. S. Bureau of Fisheries and its output will stock the waters impounded by the Authority from and including the Chickamauga to the Gilbertsville Reservoir. The Conservation Commissions of the states of Alabama and Tennessee, and we hope of Mississippi, will cooperate in the distribution of fry from this hatchery to those waters which lie within the sphere of their authority, and in the protection of the fish following their liberation.

Upon Norris Reservoir, we have had a laboratory boat under the direction of Dr. A. H. Wiebe, which has functioned for a full year.

I take pleasure in announcing that the laboratory boat for the so-called lower reservoirs is now in operation, and the investigations on these reservoirs is under way (Figure 1). This boat is in charge of Mr. Miller and Dr. Clarence Tarzwell, who has come to the Authority since I last spoke to you. This boat is constructed upon a steel hull, 70 by 20 feet in size, is powered by a 200 horsepower marine motor capable of driving the boat from 10 to 12 miles per hour, and is equipped with the most modern apparatus and paraphernalia necessary for the investigation of the water and its organic and inorganic contents. The investigations carried out on this boat will be of great importance, we hope, in throwing light upon the metamorphosis of rivers into lakes, in clarifying our understanding of what is actually going on during that change, what effect the chemical and physical changes have upon the fauna and the flora of the waters, and what effect all of these changes have collectively upon the fish therein. We hope, and believe, that as these data accumulate, we will have a sound scientific basis for carrying on a fisheries improvement program which will play an important role in the lives of the people of the Valley.

During the interval, we are not neglecting our investigational studies. A study of the fish fauna of the Valley has been progressing steadily, and we know at least what fish are present in approximately one-tenth of the 40,000 square miles which make up the Tennessee Valley. The material gathered in this connection will give us highly important information in the years to come, for we have concentrated our efforts in obtaining pre-impoundment data which must be the basis of our future studies and of our understanding as to the exact effects of impoundment.

The development of the Clinch River as a trout stream has progressed well. We have now planted 51,820 rainbow trout in that cold stream, fed as it is from the depths of the Norris Reservoir. It is interesting to note that although the first trout were planted sixteen months ago at a length of 1½ inches, the trout fishermen now are catching 12-, 13-, and 14-inch trout below Norris Dam. Dr. Tarzwell has made a study of the food supply available for fish in this river, and is reporting upon his work at this meeting.

The studies of the waters of Norris Reservoir have been carried out, as I have said, for one year by Dr. Wiebe. I would summarize the results of that year's work as follows:

Up to this time, the work on Norris Reservoir has been confined almost exclusively to observations on physical factors. A large number of plankton samples has been collected, but there has been no time to study them. When studied, these samples should throw some light on the vertical, horizontal, and seasonal distribution of plankton organisms. Enough bottom samples have been collected to indicate the extreme paucity of bottom organisms other than midge larvae, particularly *Corethra*. Sludge worms have been seen in

deeper water. Because of the physical condition in the reservoir (depth, stratification, and seasonal drawdown), the permanent bottom fauna will be limited to such organisms as can exist for shorter or longer periods without free oxygen.

The following factors have been investigated with considerable care during the late summer and fall of 1937, and are being investigated during the present season (1938): Temperature, dissolved oxygen, pH, free carbon dioxide, total alkalinity, turbidity, transparency, nitrogen, phosphorus, and hydrogen sulfide. A brief summary of results follows although space does not permit the presentation of data to prove any conclusions. These data are available in our files.

Norris Reservoir shows typical stratification with respect to temperature. A thermocline is generally present during the summer. The position of the thermocline may vary from a depth of 15 to 60 feet. During the winter the thermocline disappears and temperature conditions become uniform from surface to bottom. Replacement caused by the drawdown and by incoming water plays a more important role in bringing about this condition than the fall turnover. The range in temperature from top to bottom during August, 1937, was from 86° to 48.25°F. The horizontal distribution of temperature is uniform.

The dissolved oxygen in Norris Reservoir presents a peculiar stratification during the late summer. The maximum occurs at or near the surface. Between 20 and 25 feet a sharp decline begins and a minimum of as low as 0.1 p.p.m. is reached at from 35 to 40 feet. (The position of this layer of stagnant water changes with the level of the reservoir.) Below this depth (40 feet) the oxygen increases again to a second maximum at from 90 to 100 feet. From this depth down, the $O_2$ decreases until a second minimum (this minimum may be zero) is reached at or near the bottom. This condition prevails when the water has a depth of 75 feet or more. When the total depth is less than this (30 feet or less) there is either no stagnation or there is simple stagnation in the hypolimnion. The explanation for the peculiar vertical distribution of $O_2$ is as follows: The water near the head of the reservoir stagnates because of the organic matter carried in with the silt and from the decomposition of organisms. We have figures to show that, at times at least, the water at the head of the reservoir contains enough organic matter to completely use up the dissolved oxygen. We also have data to show that after a heavy rain the incoming silt-bearing water has an oxygen demand sufficient to reduce the $O_2$ content 50 per cent in one week. Again we have figures to show that the depletion of $O_2$ at certain levels is related to turbidity.

As indicated above, stagnation begins at the head of the reservoir. In this relatively shallow water, bottom temperature is fairly high and the water is lighter than the much colder water in the deeper

parts of the reservoir. Yet it is much cooler than the surface water. Under the influence of the drawdown near the bottom of the dam, the water moves towards the dam, but since the currents set up by the drawdown are of low velocity, the different strata of water are held intact and do not mix. Therefore, the two main factors in bringing about the peculiar stratification with respect to $O_2$ in the deeper sections of the reservoir are: (1) stagnation near the head of the reservoir and (2) density currents due to temperature stratification and the drawdown.

Space does not permit extensive discussion of this phenomenon but the subsurface currents have been determined by the vertical distribution of pH, $CO_2$, total alkalinity and turbidity measurements. Figures are available and vertical curves can be plotted for these factors that show essentially the same picture as do the curves for dissolved oxygen.

The transparency (Secchi's) disc reading may vary from 4 inches at the head of the reservoir to 10 feet or more toward the lower end. The water in Norris Reservoir is rich in nitrates but probably lacks the phosphorus necessary to make full utilization of nitrates possible. The surface water of Norris Reservoir runs high in nitrite nitrogen. This is an unusual condition.

It would be very interesting to see what the distribution of fish is with respect to dissolved oxygen. We hope to investigate this eventually.

Unfortunately, time does not permit that I enter into the details of our work. I have outlined for you very briefly only the major projects upon which progress has been made. The scope, magnitude, and importance of the fisheries problems which must occupy our attention are so great that it will take considerable time before the various results can be coordinated and general conclusions obtained. As these results accumulate, it will be my pleasure to report them to you from time to time. Great and diversified as our problems are, I believe that we are on our way.

## Discussion

**Mr. William C. Adams: Do I interpret those figures to mean that there is a layer of water over the bottom of the reservoir that is intolerant to fish life due to lack of oxygen?**

**Mr. C. C. Davis: As I get it from the curves that have been laid out, there is a layer of water at the top of the reservoir which has sufficient oxygen for fish life. This oxygen decreases as the depth increases, to practically zero at about 40 to 50 feet. Then, instead of following the normal trend of lakes, the oxygen increases until there is almost as much at a depth of approximately 90 feet as there is at the surface. Then there is a decrease from 90 feet on down to the bottom of the lake, where it may get as low as zero.**

**Mr. W. C. Adams: That is the way I interpreted it. Is there an absence of oxygen on the bottom of the lake so that the lower strata are practically uninhabitable for fish?**

Mr. C. C. Davis: Yes.

Mr. W. C. Adams: I just wanted to check that against our own biological investigations, which discovered the same condition in our deeper lakes. I would like to have you comment as to whether or not the absence of oxygen in the bottom of those reservoirs makes them more or less a desert so far as the maintenance of fish life is concerned.

Dr. R. V. Bangham: I have been at Norris for the last three weeks. This water moves downstream gradually through the season until it reaches the lake in the fall. The stratum of water where the oxygen is depleted starts at the head of the reservoir and gradually moves toward the dam. There are in the deeper water no bottom organisms of any significance.

Mr. H. S. Swingle: In our shallow lakes in Alabama we find more or less the same condition. Even in a pond that has a maximum depth of 6 feet, there is no oxygen during the summer time. During the fall of the year, however, this condition does not exist.

Mr. Adams: Then there is a period when that deep water does become productive?

Mr. Swingle: Yes.

The President: Mr. Swingle, would you infer from that that the same condition might obtain in a depth of water such as we have in the impoundments on the Tennessee, from 75 to 100 or 200 feet?

Mr. Swingle: That should occur in the same way.

The President: A turnover should be expected? That is interesting.

Mr. C. C. Davis: I feel sure that by the next annual meeting of the Society Dr. Cahn will be able to have some very definite data as to whether that condition actually does obtain in the relatively shallow reservoirs or not.

Dr. A. S. Hazzard: With regard to Mr. Adams' question, there are certain forms that are tolerant of very low oxygen conditions; in fact, are more abundant where the oxygen is low than where the oxygen is high. Chironomid larvae are found in such situations, and we have found in our studies in various parts of the country that some of the richest lakes are those which contain practically no oxygen in the bottom waters during the summer months.

# GAME FISH MANAGEMENT

CLARENCE R. LUCAS
*U. S. Bureau of Fisheries, Washington, D. C.*

ABSTRACT

This paper outlines a program of coordinated "fish management"; compares our present work with such a program; and points out the need of a change in our basic policies to permit maximum efficiency in our efforts. The paper stresses the point that fish cultural activities, stream improvement work, research, etc., are carried on independently and with somewhat different objectives in view, and that we need a central planning and administering agency to keep all efforts directed toward the common goal—"good" sport fishing.

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The management of fresh-water game fish resources has demanded a rapidly increasing amount of attention during the past fifteen years. Fishing effort has increased tremendously as the construction of thousands of miles of new roads and improvement of the old have placed most of the fishing waters within reach of the automobile. Nature alone has been no match for the drain caused by man's fishing activity. The frontier of naturally good fishing has been pushed back farther and farther until it now seems to have almost disappeared.

By the middle of the last century it had become evident that man must evolve means to control the fishing effort and to assist nature in the production of fish if he were to utilize the lakes and streams for more than incidental fishing recreation. The 1860's saw the beginning of fish culture and regulations of commercial fishing on the East Coast. Soon thereafter these conservation activities were broadened to include game fishes. Hatcheries were publicized far and wide as the solution to every depletion problem. Faith in fish culture grew to such proportions that continued despoliation of fishery resources seemed to cause no alarm.

Faith in the fish hatchery has remained strong through the years. As early as 1913, however, it was becoming increasingly evident to conservationists that artificial propagation alone was not sufficient to stem the tide of depletion. More and more hatcheries were being built, billions of fish were being planted, and yet the problem was obviously not solved.

The chief difficulty lay in the failure to attain the expected results from the unsystematic planting of fish. The large number of unsuccessful plants made it evident to some that we should know more about the natural requirements of the fishes and the conditions in the lakes and streams before we could make reasonably successful plantings. Gradually federal and state fisheries departments re-

sponded to the need for biological study of the waters. Regular scientific personnel became available for investigations of game fish as well as commercial fish. Universities furnished special training in fisheries biology. The "informed" public once more viewed the situation with a feeling of satisfaction.

Today, the trend is toward a more scientific approach to the problem of fish management. The combination of fish culture and aquatic survey is just beginning to be tested. Stocking policies are being made by the biologist, and stream and lake improvements are being specified and frequently accomplished. Efforts are being made to supply fish in accordance with the recommended policies. Conservation authorities feel that present activities and those of the future will meet the stocking needs more adequately and efficiently.

The changes in procedure just outlined give evidence that progress has been made in our activities in fresh-water fisheries conservation in the past few years. It appears, however, that even the present conservation measures might be improved. There are short-comings in present day practices, the elimination of which can result in worthwhile improvements. A description of fish management in its several phases may lead to identification of these defects in method and suggest ideas as to how they may be remedied.

In general, fish management means the controlled utilization of fishery resources by man to his best interests. The technique of fish management may be classified generally into three forms of activity: inquisitory, or that which deals with the identification of problems and the determination of means for their solution; operative, or that which makes practical application of the results of scientific studies; and administrative, or that which plans for coordinated action and arranges for its accomplishment.

Inquisitory activities include:

1. Surveys—biological, chemical, and physical studies of lakes and streams.
2. Creel census—the study of the fisherman's catch.
3. Inspections—inspection observations of fishing conditions.

The main purpose of all of these inquiries is to determine what steps we should take to build up and maintain good fishing conditions. Yield studies through the creel census combined with survey studies to determine environmental conditions provide the best guide to planned action. As the cost of these studies is rather high, however, they may often be considered impractical where fishing is comparatively light or the potential production of little value. In such situations, inspection to determine approximate conditions and set tentative stocking policies appears to be a somewhat satisfactory substitute. The inspection can at least ascertain the presence of good or poor fishing conditions and serve as a fairly reliable basis for the most desirable stocking policy.

The second form of activities, the operative, may be listed as follows:

1. Regulation—the framing and enactment of regulations as to closed seasons and waters, size and creel limits, etc., to protect the fish population as needed during spawning seasons and at other times, and the enforcement of these regulations.
2. Fish culture—the rearing of game fishes for stocking.
3. Distribution—the transportation of the fish from the hatchery and their liberation in the streams and lakes.
4. Stream and lake improvement—the modification of physical or chemical conditions in the stream or lake to increase its value in fish production.
5. Predator control—the removal of predatory fishes or of fishes that otherwise interfere with the production of the game fish crop.

The cure of stocking ills as outlined by the inquiries is carried out through the operative activities. These activities may involve regulation to protect the fish population, enlargement of the fish population through fish culture and distribution, or betterment of aquatic living conditions through "improvement" or predator control. Fish culture (with distribution) and regulation tend toward the same result and can to some extent be substituted for each other, whereas predator control and improvements are specific remedies for unsuitable conditions which neither regulation nor stocking can correct.

We can thus identify three investigational and five operative functions which may be included under fisheries management. It is obvious that these activities should be carried on together in a systematic manner if they are to work efficiently. The coordination necessary to insure the success of this "system" is supplied by the third form of activity—the administrative.

The relation of the administrative activities to those of inquiry and operation may be pictured by the following grouping:

FISH MANAGEMENT

ADMINISTRATION

INQUIRY OPERATION

Although each of the three services can in itself aid in the betterment of conditions, their maximum utility lies in a general coordination. Balanced use of the operative functions is desired in order to permit fishing with as few restrictions as possible and without excessive replacement costs. The crop of hatchery fish must be planned in relation to the stocking plans; improvements should be made with

future stocking possibilities in mind; and regulations as to closed seasons, size limits, etc., should form an integral part of a well-rounded program.

Fisheries management should properly include all of the aforementioned activities. Each one contributes to the system of conservation of our fisheries just as each phase of business management contributes to the operation of business. In this general connection let me compare fish management with the making of blood transfusions. Both are made necessary by shortages in the natural supply of materials essential for proper functioning, and both attempt to accomplish a scientific replacement of the shortages. The anemic patient may be likened to the ailing stream or lake, the consulting physician to the biologist, and the donor of the blood to the fish hatchery.

The physician studies the patient to find out the quantity and type of blood needed just as the biologist studies the waters to determine the proper remedy for the poor fishing conditions. The donor's blood must be of a "type" similar to that of the patient. Nurses, internes, the physician, the donor, and the patient are systematically brought together—and the transfusion is accomplished. Other measures to improve the condition of the patient are also undertaken in accordance with the recommendations of the physician. After the completion of the transfusion, the patient is continued under observation until his recovery is as complete as possible, and other transfusions are recommended and performed as needed.

Throughout the entire blood transfusion "management" process the activities are almost identical in principle to those of fisheries management. Limitations as to type and quantities of blood are similar to limitations as to species, fingerling sizes and numbers of fish needed. The additional medical aid given the patient may be considered as similar to stream improvement and other measures to better fishing conditions.

Methods for the conduct of business also resemble those of scientific fish management. Business provides commodities or services to satisfy demands. Efficient operation requires that the need for the commodity or service be measured as accurately as possible and that production be built up and regulated in reference to the needs.

From the foregoing we may see that fisheries conservation work will naturally form itself into a management system. We see further that this system involves simply the application of basic business management principles to our conservation problems and methods. We may assume that well-managed work developed on sound general principles will give us the most efficient results in our efforts to establish and maintain good fishing. Let us now attempt to evaluate our present work in the light of management principles.

As we have seen, management in general is the organization of all our efforts with one basic aim—to satisfy a demand. In game-fish

management this is the demand for sport fishing—for good and abundant sport fishing. Most of us hold our present positions because of that demand. Now, are we working at maximum efficiency in the production of the "goods" that the public needs or wants? It does not appear that we are. Here I would like to add that I realize that some of us are doing much better work than others, and that the progress many are making entitles them to be eliminated from criticism. On the whole, however, we are not providing the public with the best possible sport fishing. Surely our efforts are sufficiently sincere and energetic. I know of no other group which works harder and with more interest in its work than the fish culturists and biologists. Nevertheless, conditions in general are improving very slowly, if at all. What is wrong? Are our operations inadequate in their scope or are they ill-adapted to correct the deficiencies?

Undoubtedly one of our chief faults lies in the limited extent of our work in most areas. In my estimation, however, the possibility of correcting faults in our present methods of operation should also be examined. Let us disregard for the purpose of our present discussion the many criticisms we may have of details of procedure, and let us see where our work is not providing as good fishing as it should.

First we may consider fish-culture and distribution work. Although many hatcheries are yielding excellent productions of fish, we are undoubtedly wasting a very large percentage of this production through the ancient "hit or miss" plan of planting fish which is still in operation in most of the United States. Hatchery production is only roughly planned with regard to known needs and consequently fish are usually planted as available rather than in relation to requirements. Substitutions of available species are made freely for other requisitioned species; planting programs are made up in haphazard manner; and insufficient precautions are taken against the overlapping of stocking effort. While the needs for fish for most waters are not specifically known, we are not even supplying fish in accordance with the plans where stocking policies have been completed. Another defect in the methods of fish culture and distribution lies in the failure to keep records of plantings and make studies of stocking results.

Furthermore, regulations are also operated partially upon a "hit or miss" basis. Creel limits and protection of adults during spawning periods are the only broad principles which are established as effective. Research work is needed to evaluate these factors still further and to test the effectiveness of other possible regulations such as the imposition of size limits and the closure of feeder streams.

Stream improvement work likewise does not appear to be coming up to its possibilities. Basic studies are lacking as to the effectiveness of the different forms of stream improvement structures. These studies are being made gradually, but in the meantime many of these structures are being installed without adequate planning, particularly

in projects designed primarily to provide work relief. As a result the streams are often injured rather than improved.

Finally, our present scientific program is not fully adapted to our conservation needs. Admittedly much of the scientific investigation of the past has appeared to many of us to have less practical application than it should. However, the chief weakness in our investigational program lies in the amount rather than in the type of studies that have been made. For example, basic research into the ecology of fishes has hardly been started. It is also true that the possible applications of available scientific information to practical conservation problems have not all been thoroughly explored.

We have analyzed briefly the present status of conservation work as it applies to actual fishing problems. We have listed the shortcomings in method that lessen efficiency in the production of good fishing. We see that our difficulties are traceable either to a lack of sufficient activity or to poorly balanced planning or execution of the work. As examples of poor balance, it may be pointed out that fish culturists are interested in rearing fish but are almost indifferent as to the survival of these fish after planting; stream improvement technicians are more concerned with making pools in streams than in the effects of the pools they are creating; and scientists are engaged in the formulation of plans for stocking, etc., but do not follow up the plans to see that they are carried out. Comparable procedures in blood transfusion would prove very costly in human lives.

Or consider, for example, the effects of our haphazard methods as applied to the shoe business. Shoes would be produced without any reference to market demands. We would boast of increasing records in the production of No. 14 button shoes although only a few of them could ever be utilized. We would also accumulate a costly collection of foot measurements and make extensive observations upon sales and then throw our records in a pigeonhole to collect dust. Such methods in the competitive field of business would make profits impossible. Bankruptcy would result as surely as night follows day.

Does it not appear reasonable, then, to suppose that a continuation of our "hit or miss" operations will eventually end in serious repercussions? One of these days an aroused and disgusted public may decide that the results of our activities do not justify the expenditures entailed. Already thousands, possibly millions, of anglers have laid aside their rods.

We have criticized our present methods of fisheries conservation and have pointed out that the faults which we have recognized can be traced to a lack of management. How can the situation be remedied? It would be possible to achieve management through cooperation—but this method must be discarded as impractical in any carefully organized program because of the divided responsibility. The only effective form of fish management is that in which all phases of activity are united into a single well coordinated organization. The

key to effective fish management is efficient executive supervision of fish culture and scientific investigations. These executive duties are not properly the task of research men or fish culturists. Moreover, both scientists and fish culturists have plenty to do in their own respective fields.

In my estimation the work of fisheries management calls for a new type of fisheries men. They could logically be called "fish managers." These men should be empowered to direct the functions of fisheries management as needed, working out the details with the specialists in the various related fields.

I like to believe that in a few years the entire United States will be divided into areas for fisheries management purposes, with a "manager" in charge of each area. It appears logical that the following work will be concentrated in the administering offices:

1. The recording of all available information applicable to the plans for conservation work in every body of water in the area. These records will include descriptions of the waters, stocking policies, fish planting records, results of surveys and censuses, fishing reports, and other similar information.
2. The determination of (a) stocking policies with the help of such inquiry work as may be practical, (b) fish hatchery activity needs, with the help of fish culture administrators, and (c) needs for other fish conservation work. This work may be roughly or elaborately planned as the importance of the waters will demand.
3. The preparation and submission of applications and recommendations for fish, for scientific assistance, creel censuses, stream improvement, and regulations.
4. Liaison activities to arrange for definite fulfillment of all conservation needs, and preparation of statements and reports.
5. Sufficient personal inspection of all waters in the area to acquaint the manager as thoroughly as possible with local conditions.

These duties could be lessened or increased as actual trial and error might dictate. Thus, in some regions, it would no doubt be desirable to place distribution and actual planting of fish and possibly the control of natural rearing ponds and stream improvement construction under the direct supervision of the manager. The amount of direct supervision needed and that which an efficient manager could perform will have to be determined after the work is started.

When these "managers" are installed, and it seems inevitable that they will be, they will undoubtedly find it necessary to increase the use of scientific research tremendously. Fish culture will become more firmly established as it adjusts itself to a measured rather than an assumed need. We will all benefit by the change, although we may feel that we have lost some freedom as the change takes place.

What men will qualify as managers? The men we will need must be thoroughly experienced in and familiar with all the phases of fish

conservation work. They should not necessarily be highly skilled either as fish culturists or scientists. They must be observing and resourceful and work well with other men. In all, they must be good executives as well as good students of practical fish conservation.

Such men are, of course, very scarce, as no game management courses, biology courses, or fish culture training provide anything that approaches the background needed. There are a few such men available, however, and a few more are gaining the experience that should qualify them for this work. I look for great strides forward in our fisheries conservation work if and when we give these men the chance to take up the practice of fish management.

## Discussion

Acting Chairman Foster: Thank you, Mr. Lucas, for this very fine paper, which has demonstrated a great deal of thought on your part, a frank and fearless criticism of present methods and a careful analysis of what is needed for the future.

We would like to have some discussion on this paper.

Dr. John W. Scott: Perhaps as a newcomer I ought not object to there being no discussion of this very excellent paper. Although I am not a specialist at fisheries work, from my own experience and what I know about the work in my own state and in adjoining states, I believe that this very critical and suggestive paper is worthy of very careful consideration. Undoubtedly we need to know a great deal more about the environment of fishes than we do at the present time, and about the requisite factors that are needed not only for fish in general but even for different species of fish. If I were to take the time I could point out many interesting things which would bear out a number of the suggestions that have been made. I only wish that our fish warden were here in order to discuss more specifically the various subjects that have been raised in this paper. I feel sure that we are going in the right direction, that hatchery production in the past has been the main objective and we thought we were turning out fish as soon as the fingerlings were released.

We have found recently that most of these fish were entirely wasted. We have very frequently planted these small fish in streams or in places where the habitat suited older fish and did not suit small fish at all, where the food was not present,—in short, where it was a foregone conclusion that the loss would be tremendous.

I might say in this connection that a few years ago we started the development of natural retaining ponds to carry over our fish to a larger size, and by the careful selection of those ponds which have the right habitat for fingerling fish we have had some very remarkable results. In one of these ponds which was operated with the cooperation of the National Forest Service, we planted 8,000 fingerlings about an inch and a half in length, and some three months later took from that same pond 4,140 fish four or five inches long.

I would like to say that we believe that that illustrates the importance of selecting locations or rearing ponds where the natural environment is favorable for the production of fish of this size.

Mr. H. W. Shawhan: I would echo the sentiments of Dr. Scott. I have listened with a good deal of interest and pleasure to the reading of the paper and, speaking from the standpoint of a conservation administrator and not that of a fish specialist, I am even more impressed with the qualifications, specifications and characteristics so well set up for the job of fish manager.

Mr. T. C. Fearnow: I think perhaps Mr. Lucas will find in the U. S. Forest Service something of the type of administration to which he refers. In connection with fish management in the national forests there has been a coordination of the work of the U. S. Bureau of Fisheries, the State Conservation Commissions, and the Forest Service. The Forest Service is the land owner attempting to correlate the activities of these various departments and to serve in a managerial capacity.

Dr. J. E. Bost: I think this paper has fallen upon fertile soil. Too often the game departments of the different states, the forestry departments, and the U. S. Bureau of Fisheries all have tried to show us where our troubles are, and haven't shown us what to do about them. Too often, I think, the Department tells you the food in your streams is not sufficient, but they don't go any further. We people who are trying to raise fish and stock the streams of our different states are going to find, I think in the near future, that the public is going to demand more and more every year. We are not only going to try to make two fish swim where only one swam before, but we are going to have to raise the number to ten or a dozen.

I think one of the greatest things that the Bureau of Fisheries could do would be to go into the state, or into several states, and take at least one stream and show what can be done. I am from South Carolina. We have one of our best trout streams in the Saluda River, which arises close to Asheville and flows across the state. If the Bureau of Fisheries could take that stream, develop it, and help us show our legislators what can be done, then we could obtain some funds to develop the rest of our streams and our lakes. Not until then can we do it. I think we are trying to spread what is being done over too large a territory and are not finishing anything. I am speaking largely of what I have seen in the South. I have seen some fine work in other states, but it has impressed me that if we are going to make progress we must show a finished product, especially if we are going to get funds with which to work.

We have a big job in fish culture, but I think we are just scratching the surface. I think we should show the public and show our legislatures what can be done on one particular project. Then, when we do that, we are going to be able to get funds to do the rest of the job.

Furthermore, I think we are leaving the man in the field, the hatchery superintendent, too much to work out his own salvation. If it is good for us to meet here and discuss our problems, why should we not have an organization of our superintendents and their assistants, and let them get together, either by zones or states, and work out their problems, and then let them tell you men what they need and what they want?

# OBJECTIVES IN TROUT STREAM MANAGEMENT

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Abstract

For successful management objectives must be kept clearly in mind. The primary purpose of management is to provide satisfactory fishing for the largest possible number of anglers at a reasonable cost. Another objective is to provide sport rather than food. It is also important to provide good fishing throughout the season. It is believed that in heavily fished streams medium-sized rather than large trout should be the aim of management. The open season should coincide with the time fish are in best condition and weather is most enjoyable. At present the season usually opens too early. To obtain the best results management should rely on methods that have been shown to be effective. Stocking as practiced in the past has often been a complete failure. Success cannot be expected unless healthy fish are planted by proper methods in waters to which they are best suited.

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No doubt we are agreed that management, in the widest sense of the term, affords the only solution of the ever-increasing demand for more and better fishing. I do not mean to imply that through management we can fill the insatiable demands of some anglers but I do maintain that only in this way can we hope to realize the greatest possible benefits from our streams and lakes.

The time is fast approaching when conservationists and sportsmen alike will no longer be satisfied with the haphazard methods which have all too frequently prevailed in the past. The waste and inefficiency that have characterized much of the artificial propagation and stocking of our game fishes are rapidly giving way to more enlightened methods. Further progress is impeded as much by our lack of knowledge as by the natural tendency of fish-culturists to cling to old and time-honored practices.

If management is to be successful, we must have clearly in mind the goal for which we are striving. We cannot hope to get the most out of our waters unless we have sharply defined objectives toward which our efforts can be directed. It is evident, however, that the ends to be attained by fish management are not always the same and that what may be most desirable under one set of circumstances may under other conditions be of secondary importance. For example, the results desired in privately controlled waters may be quite different from those that will give greatest satisfaction in public waters. Again, the type of fishing desired in remote, little-fished waters may differ from that which would prove most satisfactory in heavily fished streams.

In general, we may safely assume that the primary purpose of management of our trout streams is to produce satisfactory fishing

for the largest possible number of anglers at a reasonable cost. There will doubtless be some question as to what constitutes satisfactory angling. The answer will vary with different conditions. It will never be possible to satisfy all anglers but it should be possible to satisfy the legitimate demands of a much larger number of anglers than at present.

First, however, anglers must realize that it is no longer possible to look upon trout, or other game fishes, primarily as a source of food. Their value for sport and recreation far transcends any possible food value and the sooner we drop the idea that the aim of trout fishing is to provide a square meal, the better it will be for all concerned. This does not mean that trout may not still provide an occasional fillip to a jaded appetite but it does mean that the days when a man could rear a family on trout and other game fishes are gone forever.

I have known of men who have taken home several hundred trout during the season, and have even had the effrontery to boast of it among their friends. The ironical part of the situation is that these men are frequently among the most vociferous in their community in demanding better conservation of fish and game. That such men are a menace to any form of conservation or management is obvious. They are not only a menace; they are preeminently selfish, for they are robbing other anglers of their just due.

Our management plans, therefore, must be developed to provide sport rather than food, and healthful and enjoyable recreation for as great a number as possible. As has frequently been pointed out, the pleasures of a day spent on a beautiful trout stream cannot be given a tangible value to be measured in dollars and cents. Although the true sportsman does not expect to carry home a full creel, he is nevertheless rarely satisfied to return empty-handed. Even the most ardent lover of nature in all its moods is both disappointed and disgusted to discover that he has been fishing a stream where there are no fish. On the other hand, if he is convinced the trout are there, even though they may have paid little attention to his lures, he will leave with a firm resolve to try again when his patience and skill may prove more effective.

It is clear that we will not be fulfilling our obligations to the public if we allow the fish to be caught out during the first few days, so that for the remainder of the season only disappointment and disillusion are in store for the credulous fisherman. Every effort should be made to spread the fishing over as long a period as possible. Much can be accomplished by the adoption of smaller creel limits and proper stocking methods so that the fish are distributed, a few at a time, along the length of a stream instead of being dumped in large numbers at a few spots that happen to be easily accessible. If there is not sufficient shelter more should be provided, since it is much harder to fish out a stream where the trout are well protected than one where little shelter is available.

The objection will be raised that it is not practicable to maintain good fishing over a long season without planting legal fish at frequent intervals. This objection probably holds for many so-called trout streams but for streams well adapted to trout the outlook is much more encouraging. An example of such a stream is Furnace Brook, Vermont, a typical New England trout stream about 25 feet wide. The stream is fished very intensively. The records show that during the last three years about 1,000 persons have fished a 4-mile section of the stream each season. Although about 50 per cent of each year's fishing was done in the first quarter of the season, we find that the percentage of fish caught closely approximated the percentage of fishing done in each quarter. For instance, in 1936 the fishing effort for the first quarter was 53 per cent of the total fishing effort for the season and the number of fish taken during this period was also 53 per cent of the total. In the second quarter 19 per cent of the total fishing resulted in 17 per cent of the season's catch. For the third quarter 14 per cent of the fishing was rewarded by 16 per cent of the take, and during the last quarter both the catch of fish and the fishing effort expended were 14 per cent of the totals for the season.

The results in 1935 and 1937 agree closely with those for 1936. It also happens that in both years the percentage of fish taken during the last quarter was greater than the percentage of fishing effort. It should be emphasized that each year all stocking in Furnace Brook was done in the fall after the close of the fishing season. The effect of the stocking on the subsequent catch is not known but it is important to remember that the supply of trout was not maintained by frequent stocking through the season.

Whether bait fishing should be prohibited as a means of conserving the fish supply is a debatable question. The elimination of bait fishing will no doubt help and it has been prohibited on many streams with good results. On the other hand, we must remember that a good fly fisherman can catch more fish than the "worm dunker" but, fortunately, good fly fishermen are rare. Furthermore, prohibition of bait fishing smacks of favoritism, since there are many fishermen who have neither the time nor the means to take up fly fishing. The best solution appears to be a compromise in which certain streams are reserved for the fly fisherman while others are open to bait fishing as well.

Another controversial question of management is the size of fish to be provided. Every angler would like to catch a 2- or 3-pound trout but in heavily fished streams it is impracticable to provide fish of that size unless they are to be reared at the hatchery—and that costs money. It is important to remember that it requires much more food to produce 100 pounds, for example, of 15- to 20-inch fish than it does to produce the same weight of 8- to 10-inch fish. The cannibalistic proclivities of large trout should also be taken into considera-

tion. In intensively fished streams very few trout can be expected to reach any considerable size before they are caught. Consequently, if large wild trout are desired streams can be opened to fishing only once every two or three years. For these reasons it is believed that in heavily fished waters at least the objective should be medium-sized trout rather than a few large fish. With smaller fish fewer fishermen will go away empty-handed.

Of paramount importance in any program of fish management is the length and time of the open season. Obviously the proper season will vary with the species of trout and the climatic and other local conditions. Spring-spawning fish require a different open season than fall spawners. Since under modern conditions the season can extend only over a portion of the year, it should coincide with the time the fish are in best condition and the weather is most enjoyable. These conditions are seldom fully realized, although there has recently been a marked improvement in this respect in several states. Even in our most northerly states the season may open on April 1 and rarely opens later than May 1. At this time trout are in poor condition after a hard winter, with very little food. Their vitality is low, their movements sluggish, and when captured they put up a very poor substitute for the vigorous fight they are capable of making several weeks later. Of course, in more southerly states the trout recover earlier but the fact remains that in most regions the season opens before the fish are in fit condition. Waters inhabited by spring-spawning trout should not, of course, be opened to fishing until the fish have fully recovered from the debilitating effects of the reproductive act.

We should consider not only the fish but also the angler, although it must be confessed that many anglers fail to appreciate our solicitude for their welfare. Anyone who has tried to bait a hook or attach a fly with half-frozen fingers will agree that a later opening date would eliminate many discomforts and thereby add to the joy of fishing.

Although it is felt that in most localities the season opens too early, it is also believed that it should extend over as long a period as is possible without endangering the supply of fish for the following year. Evidence has already been given to support the view that in the better trout streams it should be possible to provide satisfactory fishing through the summer, which is the natural vacation period. However, in regions where the streams become very low and warm during the hottest months it is evident that no fishing should be permitted until conditions improve. If there is no fall spawning to be considered a second open season may be provided in the fall, as has been done so successfully in New Jersey.

If we accept these objectives of trout stream management, we are immediately confronted with the problem as to just how they can best be attained. Some day it is hoped we may be able to answer

this question, but in the meantime the best we can do is discard methods that have been shown to be of questionable value and rely on those which are known to give at least some measure of success.

It is probable that in intensively fished waters we must depend to a large extent on artificial stocking, although there is evidence that frequently it has turned out to be a broken reed. Stocking with legal fish shortly before and during the open season has proved a success. Its chief drawbacks are the cost of rearing fish to this size and the inferior quality of the product. This latter objection can be partially overcome by better methods of rearing and also by conditioning the fish before planting.

The evidence as to the effectiveness of stocking with smaller trout is by no means so clear. In fact, with the exception of so-called barren waters, stocking with small trout has seldom been shown to be an unqualified success. Even more discouraging, from the viewpoint of the fish-culturist, is the fact that we now have conclusive evidence that many plantings have been complete failures. I do not believe that, without further information, these failures should be advanced as an argument against artificial propagation as such, but they certainly constitute a damning indictment of artificial propagation as it has often been conducted.

Much of the failure and poor results of stocking can, I believe, be traced to two fundamental weaknesses in fish-cultural practice. The first is the almost universal desire to turn out as many fish as possible. The result is overcrowding with its attendant evils of diseased and stunted fish, lacking in "pep" and vitality. Fish-culturists should by all means pay more attention to the quality of their product and less to quantity. The number of fish turned out is far less important than their size and condition.

Probably even more important is the failure to plant the right fish in the right place. Brook trout are planted in rainbow trout waters and rainbows are planted in small, cold, headwater streams better suited to brook trout. Both are planted by the thousands in streams where no self-respecting trout could be expected to live. Strains of trout that have become adjusted to a lake habitat through thousands of generations are planted in swift mountain streams where conditions are entirely different. It is not necessary to cite other examples, but it is becoming increasingly clear that we cannot expect success unless strong, healthy fish are planted by proper methods in waters to which they are best adapted, and one of the most important functions of fish management is to see that this is done.

Other measures which should receive special attention are those concerned with the modification of conditions in streams so that they afford a more suitable environment for trout. These changes include the control of pollution and various alterations of the environment ordinarily classed as stream improvement.

But even with these measures we may fall far short of our goal if

they are not backed and reenforced by proper fishing regulations, adapted to local conditions. The failure to adopt and rigorously enforce such regulations may mean the undoing of all other measures to improve fishing. They all form an integrated whole and, if management is to be successful, each must be carried out to the best of our ability.

## Discussion

Acting Chairman Foster: Thank you, Dr. Davis, for this most splendid paper. I am sure that this paper could be used almost as a Bible by fisheries administrators.

Mr. Albert M. Powell: I don't have any particular comments on the paper at all. It is very true. Where we were raising a million trout and putting out close to a million 2-, 3-, or 4-inch fish, we now produce less than 100,000 and we are getting better results than ever before. The trout do not propagate in our streams in sufficient quantities to supply the fishermen. We have, during the first part of the season, 250 to 300 fishermen per mile in our streams, and we can not stock every small stream that is supposed to be stocked, yet the fishermen have had good fishing. We have centralized our fishing facilities and we are, as other states are, in a commercial business.

Dr. Davis' paper is very, very true, and applies strictly to Maryland, because we have the conditions there that he mentions.

He spoke of the fly fishermen. We enjoy knowing that there are more and more fly fishermen on the streams because it doesn't take as many fish to stock our streams. We have had one example this year. A stream is open for fly fishing exclusively, and we haven't stocked that stream one-third as heavily as those where bait fishing is permitted. The boys get a lot of sport out of it and I think they are very well satisfied. They know the fish are there; they are not anglers enough to catch them, possibly, and they are getting wonderful sport out of it. It does not cost us as much to raise 100,000 fish as it did to raise a million, and we have put out nothing under 8 inches for the last several years.

We have tried fall stocking and tried to carry trout through the winter. We find that the hatchery stock is poor in the spring of the year. The skin of the fish seems almost wrinkled on their sides. We now stock in the spring, but feed the trout solid foods so that solid fish of good color are produced. The anglers seem fairly well satisfied with the result.

Mr. H. H. MacKay: I wish to subscribe to the principles embodied in the excellent paper submitted by Dr. Davis, and I may just give one illustration from our experience in Ontario as regards the planting of trout. For a number of years we were satisfied with the planting of fry and early fingerlings without result. Careful scrutiny of the situation in many of our streams revealed that planting fry certainly did not compensate in any way for the expense and effort involved.

As a result, about three years ago we abandoned the policy of distributing speckled trout fry and fingerlings, and are now planting only trout of yearling size or 18 months old. The results are most encouraging indeed. In addition, after the yearling trout are planted in many of our streams, we close the waters for a period of two years in order to give the fish a chance to spawn at least once before they are taken. The closure will also give the fish a chance to become acclimated before they are taken.

Our season for trout has been changed in the more heavily fished areas. Considerable fishing used to be done during the first few weeks in September, but two weeks have been taken off that period.

ACTING CHAIRMAN FOSTER: I am sure it is a matter of individual waters and individual locations. We have to depend upon the biologists to tell us whether to plant fry or fingerlings. I recall days twenty years ago when we had heated discussions on fry *versus* fingerling planting in this organization.

MR. WILLIAM C. ADAMS: Out of this whole program for the two days this is the one place where I would like to make a little contribution.

If we went back into the Transactions of the American Fisheries Society I question whether we would need to go very far to find the subject matter of all of the papers listed under the title of "Fish Management." Just the same as with all other forms of wildlife, the idea of management is something rather new in our efforts down the years to evolve a scientific use of our wildlife resources.

This thing known as management appeals to me, but as I see it, management has largely nothing to do with artificial propagation. I don't like to talk very much about my own state, but would rather pitch my discussion on general principles. Nevertheless, what we are shooting for in New York may give some ideas to some of the fish and game commissioners here in connection with the fish set-up in their own states.

When I came into the State of New York I found we had a Bureau of Fish Propagation, a Bureau of Biological Survey, a Bureau of Marine Fisheries, and a Bureau of Inland Fisheries. The work was largely to issue licenses to commercial fishermen, but certain field managerial problems had to be settled before the licenses could be issued. The man working in the Bureau of Inland Fisheries, though never having been trained as a fish culturist, learned a great many things in connection with fish life, because he relied very largely on advice from the Bureau of Biological Survey and the Bureau of Fish Propagation to determine when and where and under what conditions licenses to take fish should be issued. I am speaking now of fish for commercial purposes.

Since that time we have made progress in the organization of a new section known as Fish Distribution. The one job that remains before I can set up what I believe to be the right kind of Bureau of Fisheries is a fish manager, and that is the job that I hope will be included in our estimates for the coming fiscal year.

We are never going to be able in any state to begin to meet the demand of the anglers through our efforts in artificial propagation, and when we respond to the present pressure by raising more fish it is obvious that we are never going to have the money to begin to hope to meet that demand.

The States of the Union—I will speak now for the moment about trout—seem to fall into two groups, as I see them. States like New Jersey and Connecticut, where there are no waters that they can rely on to any great extent for natural reproduction, have one problem. Then again, in a state like New York, we have thousands of miles of trout streams that can be relied on for that purpose.

Now, in the former group of states raising fish for the rod is about their only worry. In New Jersey, in particular (and I don't mean to say anything derogatory of Connecticut because they are doing a good job), were found the pioneers who pointed the way to planting legal-sized fish. But there is more to it than that, and I believe that if we become increasingly alert and try to project ourselves into the future as regards our several states, there are a great many things that we can do that will far outweigh a similar effort, or ten times the effort, put forth in artificial propagation.

Let me be specific: In the State of New York they built the Sacandaga Reservoir. It has 50 miles of shore line. It is fed by two streams, the principal one the west branch of the Sacandaga River. The Sacandaga rises in Speculator Lake, about 17 miles from where this west branch empties into the Sacandaga Reservoir.

When the reservoir was flooded it was immediately occupied by warm-water fishes—great northern pike, wall-eyed pike, pickerel, perch, bullheads and all the

rest. But that wasn't the end of the story, because these warm-water fishes, particularly the pickerel, began to preëmpt a large portion of the 17-mile stretch of water between the reservoir and the origin of the stream. Those 17 miles are as fine a trout stream as you ever laid eyes on.

We went in and built an impassable barrier on that western branch close to the Sacandaga Reservoir, and in the future have locked warm-water fishes out of the 17 miles of that good trout stream. But we should have built the barrier before the warm-water fish entered the stream.

When they built the Gilboa Reservoir as a water supply for New York City we did not anticipate the situation there, so that the bass that immediately took possession of that reservoir went up into the north section of the Schoharie Creek, about 14 miles of a fine trout stream. Little, under-sized bass practically drove the trout out of the stream. Again after the adverse situation developed we are in the process right now of building a barrier dam on the Upper Schoharie.

We try to learn by experience. The City of New York is about to build a large reservoir on the east branch of the Delaware River. We have taken it up with the New York Water Commission, and with their engineers have perfected a plan so that in connection with that development there will be barrier dams built on all the three or four fine trout streams that will pour into the reservoir. The warm-water fishes which we know will take possession of it will never have a chance to get into those trout streams, at least certainly not by ascending the streams.

These are illustrations of what I mean by fish management. I could go on and describe to you other trout streams in New York, the upper reaches of which could be preserved as fine natural brook trout sections, if similar barrier dams were built to lock the brown trout into the lower regions of that stream. We could have each in its proper place and have a most interesting fishery.

When you come to the warm-water fishes, we know the problem of breeding the bass and we know what could be done. If we closed those territories or those sections which are the natural spawning and rearing areas we could keep more bass in the waters than we ever can hope to keep there simply by artificially propagating bass and annually stocking the water.

I could go on almost *ad infinitum.* As Dr. Davis has pointed out, stream improvement is in its infancy. I find there is some difference of opinion as to the efficacy of the work, but we believe that it has great possibilities. We must continue until we have the facts, but I sincerely hope that in every one of our states we will gradually develop a fish manager who will go hand in hand with our propagating units and our distributing units and our people who handle control measures.

For example, we have, in some of our northern lakes, conditions where the yellow perch have practically exterminated the lake trout and the brook trout or squaretail. Along the lines of the paper read by Mr. Gordon this morning we are putting in larger size lake trout and squaretails, and the evidence indicates that we are starting to get the yellow perch under control. But that could easily be a long distance proposition, whereas if we had the experienced personnel to slip half a dozen fish traps in the spring into some of those lakes and take out a few tons of yellow perch, and send them down to the hatcheries to be ground up for food, we could accelerate the change in the right direction.

I only hope that in each of our states we will increasingly get into the position to manage fish resources separately from but not independently of our propagation efforts.

Finally, I would like to hear more discussion about fall distribution of trout *versus* spring distribution. Somehow or other I can't agree with Dr. Davis that the thing to do is to shove the fish into our waters in the fall, because there seems to be everything working against the trout. The protective foliage is leaving; the food life is becoming scarcer; and the period of low water usually is in the fall. While it is an easier time to plant fish because you don't have

all the trying conditions of the spring, nevertheless you have big clear stretches of water where all forms of predators can work on the fish you plant, to say nothing of the poacher. Finally, you have anchor ice and all the thousand and one hazards that trout have to go through from the time you plant them in the fall until you expect to catch them in the spring. I believe any of us that have tried to make any kind of check on a body of water stocked in the fall as against one that has been stocked in the spring, knows the evidence that the fall planting doesn't give the results that you have from your spring planting.

As concerns this question of equality of fish turned out of a trout hatchery as against your "Simon pure" stock, I agree with Dr. Davis that no angler in the United States today can entertain the hope that he will ever be able to catch absolutely wild trout in a primitive setting.

Let's do all we can on fish management, and so far as this question of fall *versus* spring stocking is concerned, not necessarily here, but in future meetings of the Society I would like to see more experiments made, more follow-up research to see if we can lay the bones on this eternal argument as to which is the better course to pursue. I am frank to say that most of my own official family doesn't agree with me. A great many of my own men would like to put the fish out in the fall. I don't believe my men are trying to avoid the tough end of trout distribution. I think it is an honest conviction. I certainly would like to hear, either now or in another year, more reports and more studies on the spring *versus* fall distribution.

ACTING CHAIRMAN FOSTER: Thank you, Mr. Adams. I think you have broached a subject which might readily be the topic of papers in the next session, at San Francisco.

DR. H. S. DAVIS: I want to clear myself right now of the implication that I was advocating fall stocking. Nothing of the kind. What I was trying to point out was that the catch of trout in the season during that time was not due to any stocking during the season or immediately before the season. We have definitely shown that in that stream, at least, fall stocking of legal fish does not pay.

In the fall of 1936 we planted 5,000 legal trout, and less than 14 per cent of those fish were caught the following spring. We did the same thing last fall and while, of course, the full reports are not yet in, I think it is going to be considerably less than 14 per cent this year.

What I was pointing out is that the stocking was all done during the preceding season and we stocked both fingerlings and legal-sized fish.

MR. CHARLES HAYFORD: In New Jersey, of course, we are in a thickly populated area. We have 1,475 miles of trout streams. In order to get the most out of those 1,475 miles of streams, this is what we worked out. First, we made a survey of the streams. Second, we started in to produce fish to fit the conditions. Over a period of something like ten years we have had a law that the men had to make a report when they got their new licenses on the game and fish they caught the previous year. I don't think the statements are far wrong, because the average over a period of ten years seems to be about the same. Only about 50 per cent of them actually report.

Our report on fish from spring planting shows, from our license returns, that they catch 80 per cent of the legal-sized fish that we put out. That does not include the catch of the farmer nor the youngsters under 14 years old, nor the women.

Our program calls for half a million legal-sized trout a year. Our feed bill alone for the month of April was $4,800. Of course that is a high figure. It takes $45,000 to $48,000 a year for food alone. It takes nearly 1,000,000 pounds of fish food a year, so when you rear large fish it costs.

Getting back to fish management, we improve all of our streams where possible. We find we have many miles of streams that we can utilize for about a

month, some, the mountainous streams, only for two weeks. We have dammed those streams with small, natural rock dams. You wouldn't know the dams were there.

Speaking about a fish manager, we have had that for something like twenty-five years in New Jersey. Mr. Cutting, who handles all of the distribution, helps decide where all the fish go. We work together like two partners in business. We don't have to consult applications in the State of New Jersey to learn where to put the fish. It is left entirely with us. I don't suppose we plant 10,000 out of that half million trout by request. We do work with the sportsmen's groups, as they are a great help in putting those fish out and they have taken great interest in it.

In order to get the most out of it, you must have a thorough knowledge of your streams, food, conditions and your roads. We find that in the thickly populated areas our biggest revenue and our biggest support are obtained by providing fishing for the higher type of men—not that I have anything against the "one-gallus man" (I have been one myself all my life). However, those fellows who can be out, say, at one o'clock in the afternoon, get in an evening's fishing and go back home are the powers both in the legislature and in the sportsmen's clubs.

# A PROGRAM FOR THE MANAGEMENT OF FISH RESOURCES IN GREAT SMOKY MOUNTAINS NATIONAL PARK

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ABSTRACT

Ideal natural stream conditions exist over the greater part of Great Smoky Mountains National Park, and carefully planned management measures are in operation. Fishes taken for sport and food are the eastern brook trout, rainbow trout, smallmouth black bass and rock bass. Rainbow trout are used to fill the gap between the waters capable of supporting eastern brook trout and those in which smallmouth bass are native. Native species are stocked in virgin waters, in research areas, and in streams where rainbow trout are not well established.

A modern trout hatchery, operated by the U. S. Bureau of Fisheries, and thirty-five concrete rearing pools make up the physical plant. More rearing pools are planned. All stocking has been done in the fall, but later at least part of the fish may be planted in the spring prior to the opening of the fishing season.

The prohibition of natural baits insures the preservation of native stream organisms and prevents the introduction of undesirable exotic species. A creel census on representative watersheds promises to give accurate information on the yield of the streams.

## INTRODUCTION

The portions of eastern Tennessee and western North Carolina which fall within the Great Smoky Mountains National Park are becoming increasingly popular both for recreation and for the scientific study of plant and animal life. The attractions of the area scarcely need description. The rugged mountain mass, extending in a general east-west direction, follows the Tennessee-North Carolina State Line for nearly 60 miles, and varies in width from 10 to 30 miles. It ranges in elevation from 850 feet at the mouth of Abrams Creek to 6,642 feet at the top of Clingman's Dome. The major portion of this mountainous country lies in Great Smoky Mountains National Park, and is thereby preserved for all time as an area for study and recreation. Charmed by its scenic grandeur, its wonderful forests, its extremely varied and abundant plant life, and its beautiful streams of rapidly flowing clear water, the casual visitor usually seeks to return and explore its natural features in more leisurely manner.

## CHARACTER OF STREAMS

To those who love pure running water, the streams in the Great Smoky Mountains present a picture of ideal natural conditions that is not surpassed in eastern United States. The proper protection and management of these streams are considered one of the most important administrative and technical problems dealt with by the officials of the National Park Service. Fishing in season is not only permitted

but encouraged. Eastern brook trout, rainbow trout, smallmouth black bass, and rock bass are the species taken. These so-called "game" fishes are of primary importance, but there are other aquatic resources to be considered. These other forms of life, frequently ignored in a fisheries program, hold the key to a balanced stream fauna and merit the same protection as that afforded the fishes utilized for food and sport. These other forms include about fifty species of non-food fishes, at least four species of turtles, two snakes, and several species of frogs, toads, and salamanders. Besides these vertebrates there are a multitude of snails, worms, crustaceans, insects, and spiders, all of which are important in the economy of the streams. All must be preserved as examples of native stream life. To insure the preservation of the native stream life in a near natural status, and at the same time permit the taking of certain species, requires careful study and management.

The boundaries of the Great Smoky Mountains National Park will soon include approximately 440,000 acres of land. In this area are twenty-two major watersheds, all of which eventually contribute their run-off to the Tennessee River. All of these streams are permanent and free from industrial and organic pollution. The streams descend in a continuous series of pools and cascades, broken only at lower elevations by occasional shallows and longer pools of quieter water. The gradient may be as abrupt as 20 per cent, and is less than 5 per cent only in the lower portions of the streams. The water is generally clear, but becomes amber colored after heavy rainfall. On recently cut-over areas, or in streams along fresh road cuts and fills, there is noticeable silting. This condition will be only temporary in the Great Smoky Mountains National Park.

## Distribution and Management of Game Fishes

The fish-supporting streams may be classified as smallmouth-bass, rainbow-trout, or brook-trout waters. Each type of stream requires a different form of management. The bass-inhabited waters are found on the fringes of the park, in the lower reaches of the streams. On at least two major streams, Abrams Creek and Little River, falls of 12 to 20 feet limit the upstream distribution of the bass at elevations between 1,500 and 1,600 feet (Figures 1 and 2). In the absence of such natural barriers bass may range to an elevation of 2,000 feet. Inasmuch as the smallmouth bass is a native fish and one popular with many anglers, it is desirable that it be favored in its natural habitat.

Our management program for the smallmouth bass and the rock bass, which usually have the same distribution, is not yet clearly defined. It is likely that the increasing popularity of the former species will make necessary the establishment of rearing ponds and the initiation of systematic stocking. There are approximately 50 miles of

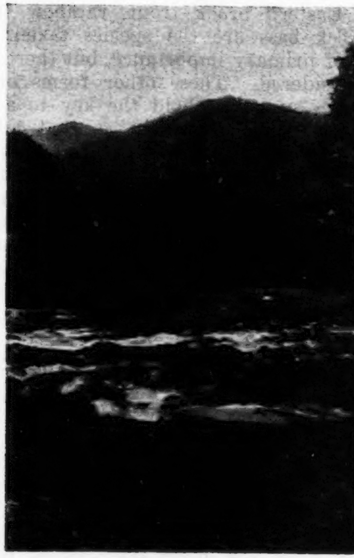

Figure 1.—The Oconalufty River, between Cherokee and Smokemont, North Carolina, is unsurpassed for smallmouth bass.

Figure 2.—Abrams Falls, at 1,400 feet elevation, limits the upstream distribution of smallmouth bass in Abrams Creek. A light cloud is hanging over the creek above the falls.

streams in which smallmouth bass and rock bass are native. At the present time both are holding their own under limited fishing.

Rainbow trout were introduced into the Great Smokies soon after 1900. At the present time there is no watershed in the park which does not harbor rainbow trout. Rainbows extend downstream as a breeding population to the upper limits of the range of the smallmouth bass, and large individuals frequently are taken well into bass water. The presence of the bass is partly responsible for the scarcity of rainbow trout in the lower portions of the streams, but is not the only factor involved. Records indicate that the temperature of the water below about 1,500 feet elevation, unless the streams are very well shaded and located on a heavily forested northerly slope, may exceed 80° F. during the warmest days of summer. This high water temperature limits the penetration of rainbows into these lower waters. The upstream limit of distribution of rainbow trout is less definite than the downstream, and varies from 3,000 to 4,500 feet. The factors that determine the upper limits of rainbow trout distribution as reported by King (1937) are:

(1) Decreasing volume of water.

(2) Unfavorable chemical conditions such as high acidity.

(3) The presence of falls which act as barriers.

The rainbow trout has usurped much of the territory formerly occupied by the native brook trout. That invasion was to be expected since rainbow trout grow larger and appear to be the more aggressive feeders. Inasmuch as rainbows are well established in the streams in Great Smoky Mountains National Park and are popular with many anglers, they are being propagated and stocked in streams which are most suited to them, and in which the preservation of the natural stream fauna can be partially sacrificed in favor of increased recreation in the form of rainbow fishing (Figures 3 and 4). In the park's research areas, where a special effort is made to preserve natural conditions an attempt is being made to eliminate the rainbow trout. At the present time the method employed consists of intensive fishing with no restocking. In one stream, the Middle Prong of the Little Pigeon River, a 9-foot dam was constructed as a barrier to the migration of rainbow trout into the research area. Only large boulders found in the streams were used in the construction. Rainbow are not stocked in streams in which they do not already occur, or in streams inhabited by brook trout or smallmouth bass.

The eastern brook trout originally occupied the territory that it now holds and much of that occupied by the rainbow. In the larger streams the brook trout rarely existed as a breeding population below 2,000 feet elevation, but large individuals ranged as low as the upper limits of the smallmouth bass waters. Factors in the decline of brook trout have been: (1) increased water temperatures and

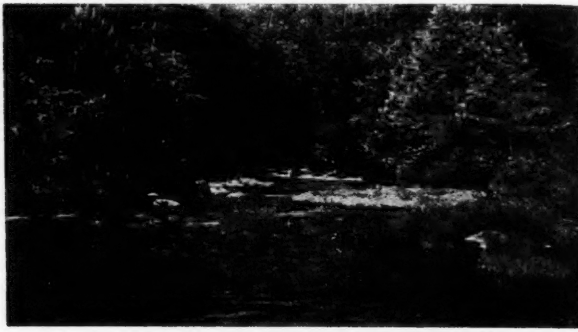

Figure 3.—Little River, at 1,700 feet elevation, is an ideal rainbow trout stream. Cascades and deep pools are more representative of the stream than this photograph indicates.

Figure 4.—Straight Fork is an average sized trout stream which supports both rainbow and brook trout.

flooding that followed the removal of the natural forest, (2) intensive fishing, including seining and dynamiting, and (3) the lack of plantings of hatchery fish. The adverse factors were so great that the brook trout almost disappeared except in the more remote virgin forests and the headwater streams. Because of the general popularity of the brook trout the National Park Service favors the reestablishment of this native species in streams where environmental conditions are now favorable (Figures 5 and 6). In local streams the natural reproduction of brook trout seems to be more effective than that of rainbow trout. The brook trout has also been found easier to propagate in our hatchery and rearing pools.

### Trout Rearing and Stocking Program

A modern trout hatchery, completed in 1936 under the supervision of the U. S. Bureau of Fisheries, supplies facilities for the production of about 600,000 trout fry annually. This hatchery is located in the park on Kephart Prong, a tributary of the Oconalufty River. In connection with the hatchery the National Park Service has built twenty-two standard concrete rearing pools. Eighteen of these are of the circular type, 25 feet in diameter, and four are rectangular, approximately 5 by 40 feet in dimensions. The pools are operated by the Bureau of Fisheries in cooperation with the National Park Service. Their annual output is conservatively estimated at 250,000 fingerlings 4 to 6 inches in length.

The National Park Service also operates a group of thirteen concrete rearing pools at the Chimneys Camp Ground on the West Prong of Little Pigeon River. These pools have a capacity of about 75,000 4-inch fingerlings per season. Most of the pools are comparatively small, and of the rectangular design. Brook trout have been found to thrive better than rainbow at this particular location, and in this type of rearing pool. The elevation is 2,700 feet, and the water supply comes from a well shaded and slightly acid stream.

The National Park Service plans to construct two more sets of rearing pools, one in Cades Cove in the west end of the park and one in Cataloochee in the east end. These ponds will provide for the rearing of trout in the portions of the park where present or proposed road developments do not offer sufficiently easy access to the hatchery and rearing pools at Kephart Prong to make for efficient transportation of fingerling trout. Labor and materials are to be obtained through the facilities of the Civilian Conservation Corps.

At the present time 400,000 trout, about half eastern brook and half rainbow, from 4 to 6 inches in length, are available annually for distribution in park streams. This number appears adequate to maintain good fishing. About 200 miles of the best trout-supporting water in the park will be open each season to anglers. At least three times that mileage exists as trout-supporting water, largely as side

**Figure 5.—The West Prong of Little Pigeon River offers excellent habitat for brook trout above 3,500 feet. Virgin forests crowd to the water's edge, providing ample shade.**

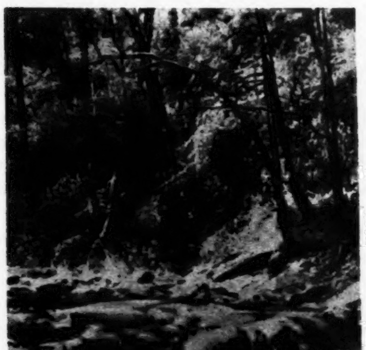

**Figure 6.—The West Prong of Little Pigeon River in January, 1938. The stream bed is severely frozen, but trout find sufficient pockets of water to enable them to exist.**

streams and head tributaries. In the past, stocking has been confined largely to the water open to fishing, and has been done at the rate of 500 to 1,000 fish per mile, depending on the volume of the stream, the fishing intensity, and the density of the fish population known to be present.

The plantings of brook trout, which have been increased in recent years, now approximately equal and eventually should exceed the plantings of rainbow. As a general rule, rainbow trout are not stocked above 3,000 feet elevation, in streams in virgin forests, in research areas, or in streams where brook trout or smallmouth bass occur or where rainbow trout are not already present.

To date, all plantings have been made in September and October. Although fishing has improved, it is likely that greater success would be attained if at least a part of the fingerlings available for stocking were held until the next spring and planted in April, just before the opening of the fishing season. We expect to undertake spring plantings as soon as facilities and funds allow. Nearly every year most of the streams are subjected to one or more periods of flood, when the volume and force of the water are sufficient to roll boulders as large as 3 feet in diameter. These floods are not only very harmful to the fish population but they also destroy many aquatic organisms which otherwise would serve as natural foods. The floods last only a day or two, but they are probably one of the most important of the natural forces that affect trout populations in the Great Smokies.

## Regulations Pertaining to Fishing

Fishing regulations in the Great Smoky Mountains National Park are carefully drawn. State licenses, issued by Tennessee or North Carolina according to the area fished, are required of the anglers. The season opens May 15, at the close of the park's spring fire season, and closes August 31. Fishing is permitted only between the hours of 5:00 a.m. and 6:30 p.m. central standard time. This period corresponds to the average number of hours of daylight during the open season. The most important regulation is that prohibiting the use of natural bait. Only one hook is allowed on the artificial lures. The Service firmly believes that to permit the use of natural fish foods as bait would not be in keeping with its policy for the protection of all native organisms that form a natural biotic balance. In addition, there is the very serious danger of the accidental introduction of exotic species of fishes or other organisms which might react adversely upon the natural environment.

The fisherman is permitted a total of ten fishes of one or all species taken, including undersized fish kept because of serious injury. During the present season the size limits are: smallmouth bass, 10 inches; rainbow trout, 8 inches; brook trout and rock bass, 6 inches. Details of the regulations undoubtedly will be altered in the future, in keeping with the development of the management program.

Most of the smaller side tributaries and the headwater streams are closed to fishing. On some of the larger watersheds it is possible to open the largest tributaries one year in three or four. The value of such streams as rearing grounds and in the production of fish foods is recognized. On the other hand, if it is found that any one of the small streams is becoming overpopulated with trout of legal size, the stream will be opened to fishing for one season or more.

Management plans include a creel census on representative streams. Beginning with the current season (1938), C. C. C. enrollees were stationed at points of entrance and exit to the streams, where they interviewed all persons fishing in the stream above the "checking stations." The census blanks have been made as simple as was possible without the sacrifice of necessary information. The fisherman is not required to sign the form, and the catch is reported in convenient size groups. The creel censuses in conjunction with the accurate stocking records that are kept for all streams should yield a clear picture of the results of our plantings. The complete census is being conducted on only three streams this season, but we are attempting to obtain representative samples of fishing returns on other streams whenever possible.

## Summary

1. The Great Smoky Mountains National Park, embracing nearly half a million acres in the heart of the Southern Appalachians, is becoming increasingly famous as an area for recreation and study of natural history.
2. Within the park are twenty-two major watersheds, including at least 600 miles of streams capable of supporting trout, and at least 50 miles of smallmouth-bass waters.
3. Rainbow trout, which have been introduced, occupy the streams at elevations of between approximately 1,500 feet and 3,000 to 4,500 feet. The smallmouth bass occupy the lower and the eastern brook trout the upper portions of the streams.
4. The distribution of the native smallmouth bass and brook trout is encouraged in waters which are adapted to them. Rainbow trout are stocked in the remaining waters.
5. Present plans call for an annual stocking of 400,000 4- to 6-inch trout per year. Fall stocking should be supplemented with spring stocking, in order to avoid the losses attributed to winter and early spring floods.
6. Fishing regulations prohibit the use of natural fish foods as bait.
7. The protection and preservation of the native stream fauna are considered paramount in the program for the management of fish resources in the Great Smoky Mountains National Park.

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# NOTES ON THE USE OF SUPPLEMENTS FOR FRESH MEAT IN THE PROPAGATION OF BROOK, RAINBOW AND BROWN TROUT IN MICHIGAN[1]

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## ABSTRACT

Brook (*Salvelinus f. fontinalis*), rainbow (*Salmo gairdnerii irideus*), and brown trout (*Salmo trutta*) fingerlings were fed diets in which fresh meats were supplemented with dry animal and plant meals. Ten diets were employed including one of pure sheep liver for comparison.

Trout fed diets that contained dry meals were reared at a lower cost per pound of trout (except in one case among the rainbow trout) than the controls.

The mortality among the trout that received sheep liver plus dry meals in the diet was generally about as low (in some instances lower) as that of the controls, whereas the loss among those trout that received trimmed pork "melts" (spleen from which fat has been trimmed) in the diet could in no case be compared favorably with the losses among the other trout. An epidemic of ulcer disease was most severe among the fish which were fed pork "melts."

Pure sheep liver yielded the greatest increase in weight among brook and rainbow trout. Among the brown trout two of the diets that contained dry meals produced better growth than did pure sheep liver.

The best conversion of food ("as purchased" basis) into body tissue was obtained from some of the diets containing dry meals.

## INTRODUCTION

For many years Michigan has been engaged in the artificial propagation of trout to be planted in the public waters of the state. This enterprise has grown to such proportions that the cost of rearing trout in the hatcheries has become a large item of expense. With a view toward reducing this cost the experiments described in this paper were carried out.

It is not necessary to present an extensive survey of the work of other investigators in the field of trout nutrition, since excellent reviews have been published by McCay (1937a and 1937b).

Because fresh liver was a rather satisfactory food conducive to the growth of young trout it has been almost the only food used in the artificial propagation of trout in Michigan's hatcheries and rearing stations. Until recently liver was a relatively inexpensive by-product of the meat-packing industry. However, the price of fresh liver has increased materially during the past few years and consequently the cost of rearing trout on this food has also increased. The purpose of these experiments, therefore, was to find some means whereby the

[1]Contribution from the Institute for Fisheries Research. This is a portion of the thesis to be submitted toward the requirements of the degree of Doctor of Philosophy in the Department of Zoology at Michigan State College.

cost of rearing trout could be reduced by supplementing the expensive fresh liver with less expensive materials. Similar studies that involved relatively fewer numbers of trout have been made by Titcomb, Cobb, Crowell and McCay (1928); McCay (1933); and McCay and Tunison (1934, 1935). In these studies dried animal and plant meals were used with success. In fact, diets containing dry meals gave better growth in some instances than did fresh liver alone.

Some of the diets used in the present study were quite similar in composition to diets used elsewhere. However, nearly every rearing station may be considered to have its own set of conditions and its own problems with regard to factors involved in the rearing of trout, so that any study made applies directly to local conditions and only indirectly to conditions elsewhere. With this in mind, experiments were set up, taking advantage of the findings of other investigators. The experiments were designed in general to be of a rather practical nature, consequently hatchery methods and routine were duplicated as nearly as possible. Larger numbers of fish were used in these experiments than are usually employed in similar nutrition studies; thus the experiment was transferred from a purely laboratory basis to a semi-production basis.

## Methods and Results

When this study was begun 96,000 brook trout fingerlings, 31,528 rainbow trout fingerlings, and 50,490 brown trout fingerlings were employed. The investigation included twelve two-week periods (except Period 2, which was only one week) extending from April 13, 1937, to September 21, 1937.[2]

The experiments were carried on at the Wolf Lake state fish hatchery located 10 miles west of Kalamazoo, Michigan, on Highway M-43. The water supply for the hatchery comes from an underground spring which has a flow of approximately 1,200 gallons per minute. The clear water flows into an open pond which was formed by building a dam across the stream valley, thereby making the pond about 100 yards long, 30 yards wide, and about 18 feet deep. A large number of brook trout had been placed in this pond at an early date, long before the hatchery was erected. Several times during the summer of 1937 specimens from this pond were examined and no evidence of external parasites or of any disease was discovered. Very few organisms such as small crustaceans, small insects or worms entered the hatchery troughs. Only after very severe rains did any quantity of silt enter the troughs and this amount was so small that the water cleared up almost immediately.

In the hatchery the water temperature was approximately 40° to

[2]On September 21, 1937, some of the trout were removed to raceways at the state fish hatchery, Benton Harbor, Michigan, where they were continued on their respective diets for another six months. The results of the continuation of this study at Benton Harbor will be reported elsewhere at a later date.

50° F. during the colder months, and about 50° to 60° F. during the warmer months. Several determinations of dissolved oxygen, free carbon dioxide, and pH of the water were made during the summer of 1937. The lowest concentration of dissolved oxygen found was 6.7 p.p.m. at 7:00 a.m. and the greatest was 9.9 p.p.m. near midnight. It was noted that in rainy weather the dissolved oxygen was about 1 p.p.m. lower than the above values. The lowest value obtained for free carbon dioxide was 1.8 and the highest value 3.24 p.p.m. The amount of free carbon dioxide was usually low when the dissolved oxygen content was high. The pH of the water was usually about 7.7; the minimum value, except during rainy weather, was 7.5 and the maximum value 8.1.

Standard hatchery troughs, located indoors, having a capacity of about 37 gallons, were used. About 5.8 gallons of water per minute flowed through each trough, except while the trout were small, when the flow was less.

A beam balance, sensitive to within 1 gram, having a capacity of 20 kilograms, was placed in the hatchery for the purpose of weighing fish at two-week intervals. The food for the fishes was weighed in small aluminum pans on a torsion balance of 4.5 kilogram capacity which was sensitive to one-fifth of a gram. The amount of food given to the fish each day was determined by the difference in weight of the food in the pan in the morning and the amount left in the pan at the end of the day. Possible error resulting from evaporation was considered negligible since the amount of food left in the pan at the end of each day was usually very small.

Since this study was to be of a practical nature, the composition and cost of diets were based on the weight of the material "as purchased" during the time of the experiment rather than on a dry weight basis which is in some cases more applicable in studies pertaining primarily to the nutrition of trout. Table 1 is a compilation of the composition and cost of the diets used in 1937.

Fresh meats were obtained from meat packing houses located in nearby cities. This material was brought into the hatchery early in the morning, ground to the desired size in the meat grinder and stored in an electric refrigerator. Under normal conditions this meat was used within three days. At the Wolf Lake hatchery the fish were ordinarily allowed to fast one day each week and this practice was followed during the present experiments. The hatchery man generally prepares ground meat by mixing a certain amount of water with it until the meat particles are separated, and the resultant thin, soupy mixture is distributed in the troughs with a spoon. This method results in considerable waste. In this feeding study the liver when fed alone was placed in the troughs in chunks without the addition of water in the same condition as it came from the grinding machine. The consistency of the meat thus compares somewhat with that of the meat-meal mixtures which were used in the experimental

**TABLE 1. COMPOSITION AND COST OF DIETS "AS PURCHASED," 1937**

| Ingredients | Cost per pound | Percentage composition of Diet Nos. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2 | 4 | 6 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
| Fresh sheep liver | $0.0850 | 100.0 | 50.0 | ---- | 50.0 | 30.0 | 50.0 | 50.0 | ---- | ---- | ---- |
| Fresh pork "melts" (trimmed) | 0.0350 | ---- | ---- | 75.0 | ---- | ---- | ---- | ---- | 75.0 | 60.0 | 75.0 |
| Vacuum whitefish meal | 0.0300 | ---- | 16.7 | 8.3 | 13.3 | 20.0 | ---- | ---- | 5.0 | 10.0 | ---- |
| Cottonseed meal | 0.0240 | ---- | 16.7 | 8.3 | 13.3 | 20.0 | ---- | 13.3 | 5.0 | 10.0 | ---- |
| Oatmeal | 0.0304 | ---- | ---- | ---- | 10.0 | 10.0 | 30.0 | 10.0 | 10.0 | 10.0 | ---- |
| Skim milk powder, roller process | 0.0560 | ---- | 16.7 | 8.3 | 13.3 | 20.0 | 20.0 | 13.3 | 5.0 | 10.0 | ---- |
| "Rowena" dog biscuits, No. 20 | 0.0515 | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | 25.0 |
| Grasshopper meal | 0.1000 | ---- | ---- | ---- | ---- | ---- | ---- | 13.3 | ---- | ---- | ---- |
| Water (shown as per cent by weight of rest of diet) | | ---- | 33.3 | ---- | 33.3 | 50.0 | 33.3 | 33.3 | ---- | 25.0 | 11.1 |
| Cost per pound before May 31 (Periods 1 to 4) | | $0.0850 | 0.0608 | 0.0354 | 0.0602 | 0.0505 | 0.0628 | 0.0695 | 0.0348 | 0.0350 | 0.0391 |
| Cost per pound after June 1[1] (Periods 5 to 12) | | 0.0850 | 0.0608 | 0.0504 | 0.0602 | 0.0505 | 0.0628 | 0.0695 | 0.0498 | 0.0470 | 0.0541 |

[1]After June 1 the price of pork "melts" was increased from $0.035 to $0.055 per pound.

feeding. In the preparation of diets containing meat and dry meal, the meal preparations were made in advance by mixing the proper proportion of the various kinds of meal and storing them in large cans. Rations of meat and meal, sufficient for three days, were then mixed and stored in the refrigerator until used. The mixture was kept in storage for twelve hours before it was fed to the trout to allow sufficient time for the meat juices to be absorbed by the dry meal and, therefore, prevent them from being washed down the drain at feeding time. In most of the diets there was not sufficient moisture in the meat to make a feeding mixture of suitable consistency. It was necessary, therefore, to add some water. Water was added to the meat first and then the dry meal stirred into the soupy mixture of meat and water. In order to reduce all of the feeding mixtures to the same consistency it was necessary to try several different quantities of water until the proper amounts were determined. The amount of water added to the diets to bring about a suitable feeding mixture is shown in Table 1. The amount of water is stipulated in terms of the percentage of the weight of the meat and meal mixture. For instance, when preparing Diet 4, 33.3 pounds of water were added to 100 pounds of the meat-meal mixture. The added water, therefore, made up 25 per cent of the final mixture, but was equal to 33.3 per cent of the remainder of the diet. When determining the amount of food used by the trout each day a correction was made for the water so that the amounts of food eaten appear comparable on an "as purchased" basis. This method of preparation of food is essentially the same as that used at the Cortland Experimental Hatchery, New York (McCay and Tunison, 1935).

The usual hatchery routine was followed as nearly as possible so that when the hatchery fish were fed once per day the experimental fish were fed once; when the hatchery fish were fed twice a day, the experimental fish were fed twice a day. Many trout culturists recommend feeding only an amount equal to a certain per cent of the body weight of the trout each day, claiming that this method results in better food conversion. However, in this experiment the practice of offering all that the fish would eat at each feeding was followed. At first the fish were given an amount which was probably less than they would eat. If after fifteen minutes all the food had been consumed, more was given until the fish refused to eat. An ideal method would be to put into the trough the precise amount the fish would eat. However, it was difficult to know the exact quantity that would be consumed, so a slight excess of food usually was allowed to remain in the trough. From experience one learned quickly the amount of food that the fish probably would eat during the course of the day. A slightly larger amount, therefore, was weighed into the pan and taken into the hatchery room.

The food mixtures were of about the consistency of freshly ground liver, sometimes slightly more firm, and were placed in the trough in

large chunks, several to each trough so that each fish probably had an equal opportunity to obtain food. After a short time the fish became accustomed to feeding in this manner and vigorously attacked the chunks of food. The hatchery man has claimed that with this method the fish do not have an equal opportunity to feed, that the big fish monopolize the food and prevent the small fish from obtaining a sufficient amount to eat, and points out as evidence the great range in size of the fish so fed. It is true that the size range of the trout of these experiments was greater than that of fish in the production troughs, but I believe that the difference was not due to the method of feeding but to the removal of the smaller fish from the foot of the production trough when it was necessary to reduce crowding. Such thinning tends toward uniformity in the size of the fish. In the experimental work no selection of this sort took place. Every sample removed from the trough was taken at random so that no particular size group was removed or remained. This practice resulted in a wide range of sizes. Observations made at the time of feeding indicate that each fish had about an equal opportunity to feed adequately.

The prices for the dry meals are computed as of April 1, 1937, the time at which they were purchased (Table 1). Some fluctuations in price occurred during the term of the experiment, but these changes were ignored. The price of pork "melts" was increased after June 1 from \$0.035 to \$0.055 per pound, and this change in price was recognized in the cost figures of the experiment. The price quoted on grasshoppers in the present study could, no doubt, be materially reduced if these insects were collected locally in sufficient quantities. In the event of a decreased cost Diet 20 could be given favorable consideration, since the mortality among the trout given this diet was low and the growth fair.[3]

In a personal communication from Mr. W. M. Keil of the U. S. Forest Service the writer was informed that in feeding trials conducted about 1910 a diet composed of beef liver plus pressed locust or grasshopper from Argentina was found unsatisfactory and caused increased mortality if the grasshoppers constituted more than about 33 per cent of the mixture. A noticeable increase in mortality did not occur among the fish that received a diet containing less than 33 per cent grasshoppers as compared to the fish in the control lot which were fed only beef liver. In growth the controls surpassed the fish whose diet included pressed grasshoppers. Because beef liver was still an inexpensive article at the time of the trials, no further experiments were conducted.

At the end of each two-week period the figures of total weight of food placed in each trough were reduced, by means of correction factors, to include only the weight of the food before water was added.

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[3]With regard to the use of grasshoppers as food for hatchery trout, the only published reference found so far is contained in the discussion following a paper published by Titcomb, Cobb, Crowell and McCay, (1928).

Consequently the computed food conversion factors refer only to the food as purchased.

The food conversion factor for a given length of time is the ratio of the amount of food fed to the increase in weight. These quantitative figures are usually expressed in grams. The formula employed in this study may be stated as follows:

$$\text{F. C. F.} = \frac{\text{Grams of food given per thousand fish}}{\text{Increment in weight in grams per thousand fish}}$$

The food given per thousand fish was obtained as follows:

$$\frac{\text{Total food given}}{\text{Average number of fish fed during period}} \times 1{,}000$$

The mean of the number of trout at the start and at the end of the period was taken as the average number of fish during a given period.

Table 2 contains the average food conversion factors for the first four periods (April 13 to June 1) for all three species, for the last two periods (June 1 to June 29) for the brook trout, and the last eight periods (June 1 to September 21) for the rainbow and brown trout. The table also shows the cost of food used to rear one pound of trout based on the work done during 1937. The figures on the price of food per pound are shown in the last two rows of Table 1. The food conversion factors are among the most important data disclosed in this kind of study, since from the price of the ingredients of a diet and the food conversion factor for that diet one may readily compute the cost to rear a pound of trout on the diet chosen by multiplying the conversion factor by the cost per pound of the diet. The cost of the ingredients of a diet varies from time to time. Although the food conversion factors are by no means fixed values, they are probably rather constant, all other factors being equal.

The trout employed in this experiment had been feeding for about six weeks before the study started. They had been fed chiefly fresh beef liver which was supplemented as time went on with increasing amounts of fresh sheep liver so that for about ten days before they were transferred to the experimental diets the trout had been receiving only sheep liver.

The brook trout were divided equally according to weight and put into twenty standard hatchery troughs. Similarly the rainbow trout were divided and placed in ten troughs, and the brown trout in ten troughs. Thus at the beginning of the experiments there were about 4,805 brook trout per trough, 3,153 rainbow trout per trough, and 5,059 brown trout per trough. The average weights per thousand fish of these three species were 377.5 grams, 360.4 grams, and 225.4 grams respectively.

The troughs in the hatchery were arranged in two rows. Each trough in the lower row received its supply of water from the outlet of the trough in the upper row. The arrangement of troughs of fish

TABLE 2. SUMMARY OF FOOD CONVERSION FACTORS, AND COST OF FOOD TO REAR ONE POUND OF TROUT

| Diet No. | Average food conversion factor: Periods 1 to 4 | Periods 5 to 12[1] | Periods 1 to 12[1] | Cost of food[2] to rear one pound of trout: Periods 1 to 4 | Periods 5 to 12[1] | Periods 1 to 12[1] |
|---|---|---|---|---|---|---|
| | | | **Brook Trout** | | | |
| 2 | 2.573 | 4.468 | 3.204 | $0.2187 | $0.3798 | $0.2723 |
| 4 | 2.423 | 3.288 | 2.711 | 0.1473 | 0.1999 | 0.1648 |
| 6 | 2.981 | 4.123 | 3.362 | 0.1055 | 0.2078 | 0.1396 |
| 17 | 2.651 | 3.361 | 2.887 | 0.1596 | 0.2023 | 0.1738 |
| 18 | 2.606 | 3.491 | 2.900 | 0.1316 | 0.1763 | 0.1465 |
| 19 | 3.848 | 4.072 | 3.924 | 0.2417 | 0.2557 | 0.2464 |
| 20 | 2.765 | 3.651 | 3.060 | 0.1922 | 0.2537 | 0.2127 |
| 21 | 3.176 | 4.558 | 3.637 | 0.1105 | 0.2270 | 0.1493 |
| 22 | 3.176 | 4.422 | 3.591 | 0.1112 | 0.2078 | 0.1434 |
| 23 | 4.165 | 5.144 | 4.491 | 0.1628 | 0.2783 | 0.2013 |
| Average | 3.036 | 4.058 | 3.377 | $0.1581 | $0.2389 | $0.1850 |
| | | | **Rainbow Trout** | | | |
| 2 | 3.084 | 3.938 | 3.652 | $0.2621 | $0.3347 | $0.3104 |
| 4 | 3.020 | 3.811 | 3.547 | 0.1836 | 0.2317 | 0.2157 |
| 6 | 3.606 | 5.231 | 4.689 | 0.1273 | 0.2636 | 0.2182 |
| 17 | 3.190 | 3.937 | 3.688 | 0.1920 | 0.2370 | 0.2220 |
| 18 | 3.314 | 3.854 | 3.673 | 0.1674 | 0.1946 | 0.1855 |
| 19 | 4.804 | 5.318 | 5.146 | 0.3017 | 0.3340 | 0.3232 |
| 20 | 3.993 | 3.913 | 3.939 | 0.2775 | 0.2720 | 0.2738 |
| 21 | 4.673 | 6.191 | 5.684 | 0.1626 | 0.3083 | 0.2597 |
| 22 | 3.853 | 6.238 | 5.442 | 0.1349 | 0.2932 | 0.2404 |
| 23 | 4.834 | 6.441 | 5.905 | 0.1890 | 0.3485 | 0.2953 |
| Average | 3.837 | 4.887 | 4.537 | $0.1998 | $0.2818 | $0.2574 |
| | | | **Brown Trout** | | | |
| 2 | 3.845 | 4.462 | 4.256 | $0.3268 | $0.3793 | $0.3618 |
| 4 | 3.479 | 3.890 | 3.753 | 0.2115 | 0.2365 | 0.2282 |
| 6 | 4.314 | 4.544 | 4.467 | 0.1527 | 0.2290 | 0.2036 |
| 17 | 3.401 | 3.886 | 3.724 | 0.2047 | 0.2339 | 0.2242 |
| 18 | 3.578 | 3.969 | 3.838 | 0.1807 | 0.2004 | 0.1938 |
| 19 | 5.226 | 5.200 | 5.208 | 0.3282 | 0.3266 | 0.3271 |
| 20 | 4.255 | 4.166 | 4.195 | 0.2957 | 0.2895 | 0.2916 |
| 21 | 4.654 | 5.262 | 5.059 | 0.1620 | 0.2620 | 0.2287 |
| 22 | 4.220 | 5.199 | 4.872 | 0.1477 | 0.2444 | 0.2122 |
| 23 | 4.330 | 6.660 | 5.883 | 0.1693 | 0.3603 | 0.2966 |
| Average | 4.130 | 4.724 | 4.526 | $0.2197 | $0.2762 | $0.2568 |

[1]Brook trout experiment was discontinued at end of Period 6. "Periods" for this species therefore are 5 to 6 and 1 to 6 instead of 5 to 12 and 1 to 12.

[2]The cost per pound of food is shown for the various diets in the last two rows of Table 1.

receiving the ten different diets was such that the diet numbers occurred in the same order in each of four groups of ten troughs in the upper row. A duplicate arrangement existed in the lower row, and, therefore, the diet given to the fish in an upper trough was the same diet as that given to the fish in the lower trough which received its water supply from the trough above. It was possible for some food to pass from an upper to a lower trough. However, the quantity of food which could have passed into a lower trough was insignificant when compared with the amount consumed by the fish.

At the end of Period 2 (May 4) some of the trout, which were weighed, were transferred from each trough to other troughs that

TABLE 3. RATE OF GROWTH

| Diet No. | On April 13, 1937 | Grams per thousand trout — At end of Period Nos. 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Brook Trout** | | | | | | | | | | | | | |
| 2 | 377.5 | 625 | 847 | 1,317 | 2,048 | 2,720 | 3,970 | ........ | ........ | ........ | ........ | ........ | ........ |
| 4 | 377.5 | 545 | 670 | 1,126 | 1,866 | 2,676 | 3,663 | ........ | ........ | ........ | ........ | ........ | ........ |
| 6 | 377.5 | 604 | 736 | 1,210 | 1,864 | 2,579 | 3,564 | ........ | ........ | ........ | ........ | ........ | ........ |
| 17 | 377.5 | 547 | 647 | 1,050 | 1,659 | 2,377 | 3,304 | ........ | ........ | ........ | ........ | ........ | ........ |
| 18 | 377.5 | 506 | 599 | 956 | 1,440 | 1,969 | 2,666 | ........ | ........ | ........ | ........ | ........ | ........ |
| 19 | 377.5 | 471 | 535 | 821 | 1,246 | 1,777 | 2,395 | ........ | ........ | ........ | ........ | ........ | ........ |
| 20 | 377.5 | 542 | 632 | 1,005 | 1,691 | 2,349 | 3,149 | ........ | ........ | ........ | ........ | ........ | ........ |
| 21 | 377.5 | 550 | 678 | 1,076 | 1,715 | 2,374 | 3,259 | ........ | ........ | ........ | ........ | ........ | ........ |
| 22 | 377.5 | 525 | 632 | 979 | 1,474 | 2,105 | 2,813 | ........ | ........ | ........ | ........ | ........ | ........ |
| 23 | 377.5 | 510 | 580 | 882 | 1,226 | 1,656 | 2,346 | ........ | ........ | ........ | ........ | ........ | ........ |
| Average | 377.5 | 542 | 656 | 1,042 | 1,623 | 2,258 | 3,113 | ........ | ........ | ........ | ........ | ........ | ........ |
| **Rainbow Trout** | | | | | | | | | | | | | |
| 2 | 348 | 521 | 689 | 1,076 | 1,670 | 2,293 | 3,041 | 4,132 | 5,871 | 7,908 | 10,503 | 12,762 | 15,097 |
| 4 | 351 | 552 | 661 | 1,010 | 1,490 | 1,983 | 2,429 | 3,299 | 4,504 | 6,164 | 8,020 | 9,873 | 11,672 |
| 6 | 327 | 523 | 681 | 915 | 1,337 | 1,735 | 2,099 | 2,858 | 3,710 | 4,911 | 6,316 | 7,711 | 9,130 |
| 17 | 371 | 541 | 652 | 1,029 | 1,577 | 2,105 | 2,626 | 3,541 | 4,799 | 6,452 | 8,461 | 10,162 | 12,095 |
| 18 | 363 | 504 | 589 | 907 | 1,387 | 1,804 | 2,258 | 3,023 | 3,974 | 5,176 | 6,553 | 8,269 | 9,719 |
| 19 | 384 | 489 | 580 | 813 | 1,158 | 1,536 | 1,991 | 2,560 | 3,300 | 4,274 | 5,418 | 6,413 | 7,356 |
| 20 | 359 | 501 | 579 | 845 | 1,286 | 1,765 | 2,260 | 3,188 | 4,239 | 5,737 | 7,451 | 9,020 | 10,485 |
| 21 | 379 | 542 | 632 | 915 | 1,319 | 1,684 | 2,109 | 2,781 | 3,636 | 4,677 | 5,722 | 6,704 | 7,685 |
| 22 | 362 | 547 | 653 | 942 | 1,344 | 1,707 | 2,019 | 2,606 | 3,340 | 4,148 | 5,117 | 6,212 | 7,126 |
| 23 | 359 | 493 | 587 | 812 | 1,138 | 1,495 | 1,908 | 2,568 | 3,340 | 4,289 | 5,486 | 6,524 | 7,443 |
| Average | 360 | 521 | 630 | 926 | 1,371 | 1,814 | 2,274 | 3,056 | 4,071 | 5,374 | 6,905 | 8,365 | 9,781 |
| **Brown Trout** | | | | | | | | | | | | | |
| 2 | 222 | 342 | 411 | 612 | 847 | 1,061 | 1,387 | 1,960 | 2,660 | 3,255 | 3,989 | 4,741 | 5,518 |
| 4 | 223 | 317 | 363 | 542 | 775 | 983 | 1,258 | 1,695 | 2,358 | 3,068 | 3,985 | 4,823 | 5,646 |
| 6 | 202 | 318 | 362 | 522 | 703 | 927 | 1,170 | 1,572 | 2,109 | 2,866 | 3,771 | 4,849 | 5,752 |
| 17 | 214 | 308 | 363 | 538 | 740 | 923 | 1,193 | 1,684 | 2,276 | 2,962 | 3,684 | 4,376 | 5,267 |
| 18 | 232 | 316 | 365 | 546 | 701 | 873 | 1,077 | 1,433 | 1,881 | 2,379 | 2,949 | 3,776 | 4,606 |
| 19 | 242 | 307 | 373 | 467 | 628 | 816 | 1,003 | 1,335 | 1,742 | 2,183 | 2,706 | 3,170 | 3,889 |
| 20 | 244 | 327 | 373 | 502 | 689 | 921 | 1,148 | 1,564 | 2,120 | 2,830 | 3,568 | 4,439 | 5,089 |
| 21 | 214 | 308 | 349 | 513 | 710 | 904 | 1,133 | 1,522 | 1,971 | 2,568 | 3,193 | 3,902 | 4,824 |
| 22 | 237 | 320 | 371 | 538 | 766 | 960 | 1,215 | 1,614 | 2,143 | 2,865 | 3,498 | 4,278 | 5,202 |
| 23 | 224 | 324 | 366 | 532 | 729 | 844 | 1,086 | 1,438 | 1,993 | 2,355 | 3,158 | 4,423 | 5,373 |
| Average | 225 | 319 | 370 | 531 | 729 | 921 | 1,167 | 1,582 | 2,125 | 2,733 | 3,450 | 4,278 | 5,117 |

had become available. Thus the number of troughs occupied by each group was doubled but no reduction in numbers of trout occurred at this transfer. It was necessary to remove some fish at intervals from the experimental lots to avoid crowding. Although the results are based on the number of fish in the various lots, these reductions were made on the basis of weight, since counting such large numbers of fish was impossible with the amount of assistance available. Therefore, whenever these "thinnings" were made, a sufficient number of individuals were removed so that an equal weight of fish remained in each trough. The weight of fish that remained was then converted into numbers by means of the known number per kilogram determined at the time of "thinning."

It was intended at the beginning of the experiments that the "thinnings" would be made at regular intervals, but due to conditions beyond the control of the investigator it was inconvenient to do so, with the result that the removals were made whenever possible, but always at the end of a period. Reduction in numbers occurred at the end of Periods 3 (May 18) and 6 (June 29). On each occasion the weights of fish per trough were equalized for each of the three species. The entire lot of brook trout was removed from the

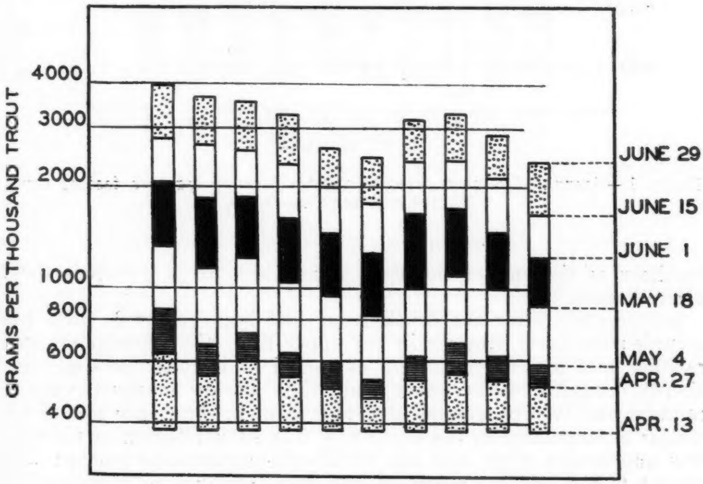


Figure 1.—Growth in weight of brook trout on various diets during each feeding period. Plotted on logarithmic scale.

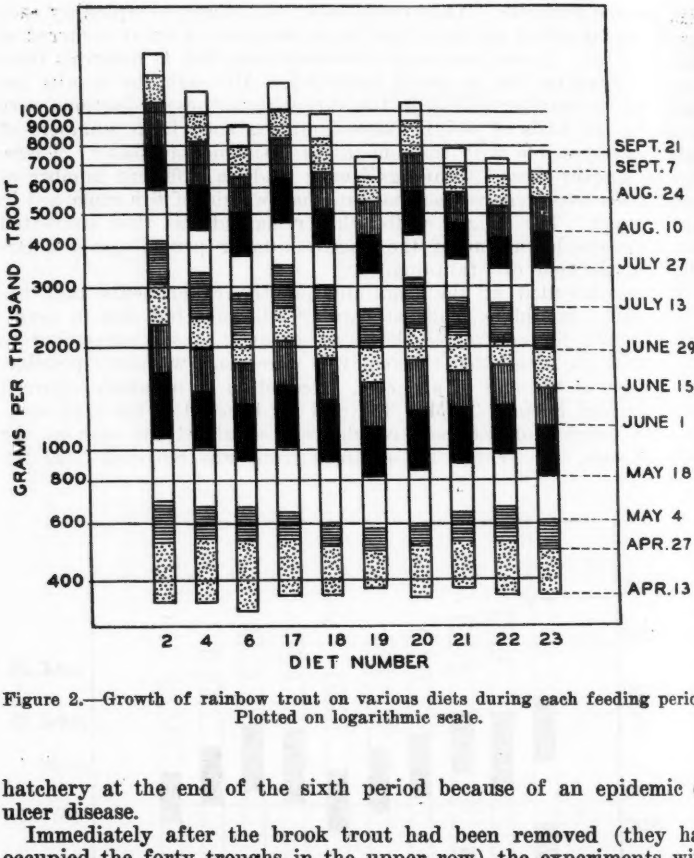


**Figure 2.—Growth of rainbow trout on various diets during each feeding period. Plotted on logarithmic scale.**

hatchery at the end of the sixth period because of an epidemic of ulcer disease.

Immediately after the brook trout had been removed (they had occupied the forty troughs in the upper row) the experiments with rainbow and brown trout were expanded to include the space previously occupied by the brook trout, thus placing twenty troughs of rainbow and twenty troughs of brown trout in the upper row with a similar arrangement in the lower row. The redistribution of the rainbow and brown trout does not vitiate the conclusions reached with respect to the relative values of the diets, although such redistribution did in all probability influence the growth rate and mortality.

At intervals of two weeks all of the fish in each trough were transferred to a wire basket. The basket of fish was then lifted from the water and allowed to drain until the steady flow broke into drops.

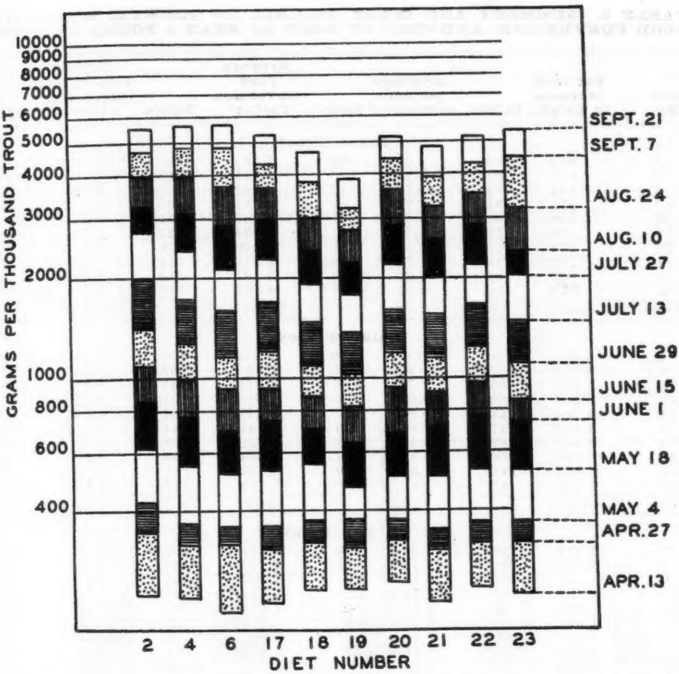


**Figure 3.—Growth of brown trout on various diets during each feeding period. Plotted on logarithmic scale.**

At this point the basket of fish was placed in a bucket of water on the balance and the weight of the fish computed. The total number of fish in each trough being known, the weight per thousand was readily calculated. The weight obtained in the above manner is commonly called the "wet weight" which includes some water, computed by Embody (1937) to equal about 5.99 per cent of the "wet weight." By weighing the entire lot no error resulted from sampling, and considerable time was saved because the fish did not have to be counted. Occasional checks were made in order to be certain that an accurate record was being kept of the number of fish in each trough. The average weight in grams per thousand fish at the end of each period is shown in Table 3 for each diet and each species. The bar charts of Figures 1, 2, and 3 are based on the data in Table 3. The per cent increase in weight of fish for the entire term of the experiment is shown in Table 4.

**TABLE 4. SUMMARY AND INDEX FIGURES OF GROWTH, MORTALITY, FOOD CONVERSION, AND COST OF FOOD TO REAR 1 POUND OF TROUT**

| Diet No. | Per cent increase in weight | Index[1] | Average per cent mortality[2] | Index | Average food conversion factor[3] | Index | Cost of food to rear one pound of trout | Index |
|---|---|---|---|---|---|---|---|---|
| | | | | **Brook Trout** | | | | |
| 2 | 952 | 100 | 5.78 | 100 | 3.204 | 100 | $0.2723 | 100 |
| 4 | 870 | 91 | 5.94 | 103 | 2.711 | 85 | 0.1648 | 61 |
| 6 | 844 | 89 | 13.72 | 237 | 3.362 | 105 | 0.1396 | 51 |
| 17 | 775 | 81 | 5.24 | 91 | 2.887 | 90 | 0.1738 | 64 |
| 18 | 606 | 64 | 3.52 | 61 | 2.900 | 91 | 0.1465 | 54 |
| 19 | 534 | 56 | 8.72 | 151 | 3.924 | 122 | 0.2464 | 90 |
| 20 | 734 | 77 | 3.55 | 61 | 3.060 | 96 | 0.2127 | 78 |
| 21 | 763 | 80 | 13.73 | 238 | 3.637 | 114 | 0.1493 | 55 |
| 22 | 645 | 68 | 5.20 | 90 | 3.591 | 112 | 0.1434 | 53 |
| 23 | 521 | 55 | 9.63 | 167 | 4.491 | 140 | 0.2013 | 74 |
| Mean (11 weeks) | | .... | 7.50 | .... | 3.377 | .... | $0.1850 | .. |
| | | | | **Rainbow Trout** | | | | |
| 2 | 4,088 | 100 | 0.67 | 100 | 3.652 | 100 | $0.3104 | 100 |
| 4 | 3,139 | 77 | 0.81 | 121 | 3.547 | 97 | 0.2157 | 69 |
| 6 | 2,433 | 60 | 1.71 | 255 | 4.689 | 128 | 0.2182 | 70 |
| 17 | 3,255 | 80 | 0.64 | 96 | 3.688 | 101 | 0.2220 | 72 |
| 18 | 2,596 | 64 | 0.92 | 137 | 3.673 | 101 | 0.1855 | 60 |
| 19 | 1,941 | 47 | 0.66 | 99 | 5.146 | 141 | 0.3232 | 104 |
| 20 | 2,809 | 69 | 0.80 | 119 | 3.939 | 108 | 0.2738 | 88 |
| 21 | 2,032 | 50 | 1.41 | 210 | 5.684 | 156 | 0.2597 | 84 |
| 22 | 1,877 | 46 | 1.34 | 200 | 5.442 | 149 | 0.2404 | 77 |
| 23 | 1,965 | 48 | 4.45 | 664 | 5.905 | 162 | 0.2953 | 95 |
| Mean (23 weeks) | | .... | 1.32 | .... | 4.537 | | $0.2574 | .... |
| | | | | **Brown Trout** | | | | |
| 2 | 2,348 | 100 | 1.00 | 100 | 4.256 | 100 | $0.3618 | 100 |
| 4 | 2,405 | 102 | 3.11 | 311 | 3.753 | 88 | 0.2282 | 63 |
| 6 | 2,452 | 104 | 6.15 | 615 | 4.467 | 105 | 0.2036 | 56 |
| 17 | 2,237 | 95 | 2.73 | 273 | 3.724 | 88 | 0.2242 | 62 |
| 18 | 1,943 | 83 | 3.43 | 343 | 3.838 | 90 | 0.1938 | 54 |
| 19 | 1,625 | 69 | 3.27 | 327 | 5.208 | 122 | 0.3271 | 90 |
| 20 | 2,158 | 92 | 3.73 | 373 | 4.195 | 99 | 0.2916 | 81 |
| 21 | 2,040 | 87 | 5.39 | 539 | 5.059 | 119 | 0.2287 | 63 |
| 22 | 2,208 | 94 | 5.83 | 583 | 4.872 | 114 | 0.2122 | 59 |
| 23 | 2,284 | 97 | 16.09 | 1,609 | 5.883 | 138 | 0.2966 | 82 |
| Mean (23 weeks) | | .... | 5.07 | .... | 4.526 | | $0.2568 | |

[1]The value of the control (Diet 2) is considered as 100. In the index figures pertaining to per cent increase in weight a value of less than 100 means poorer growth. In the index figures pertaining to average per cent mortality, average food conversion factor, and cost of food to rear one pound of trout a value less than 100 means respectively lower mortality, lower food conversion factor (better conversion of food into body weight), and lower cost of food to rear one pound of trout.

[2]Average per cent mortality is the average of the per cent of trout lost each period.

[3]Average food conversion factor is the average of the food conversion factors for each period.

Weight alone is not a satisfactory measure of growth of an animal. Length measurements as well as measurements of individual parts of the body are sometimes necessary for an adequate knowledge of the progress of growth. The practice of determining growth by weight only is customary in Michigan's hatcheries, and for that reason only weights were used in this experiment.

It was usually necessary to remove from the troughs the accumulated refuse and the sediment which came in with the water supply.

Thus at the beginning and at the end of each day a small brush was used to remove these materials from the sides and bottom of the trough. This cleaning was done very carefully so that none of the fish was injured.

At the time of the morning "clean-up" the number of dead fish, if any, was recorded. Dead fish were removed from the troughs and examined to determine, if possible, the cause of death. The percentage of fish lost during a period was determined by dividing the number lost by the number present at the start of the period. Table 4 summarizes the losses which occurred during the various periods of this experiment. The mortality record is very important in a nutrition experiment, since it is a good index of the value of a diet. Figures 4, 5 and 6 compare the losses that occurred on each diet.

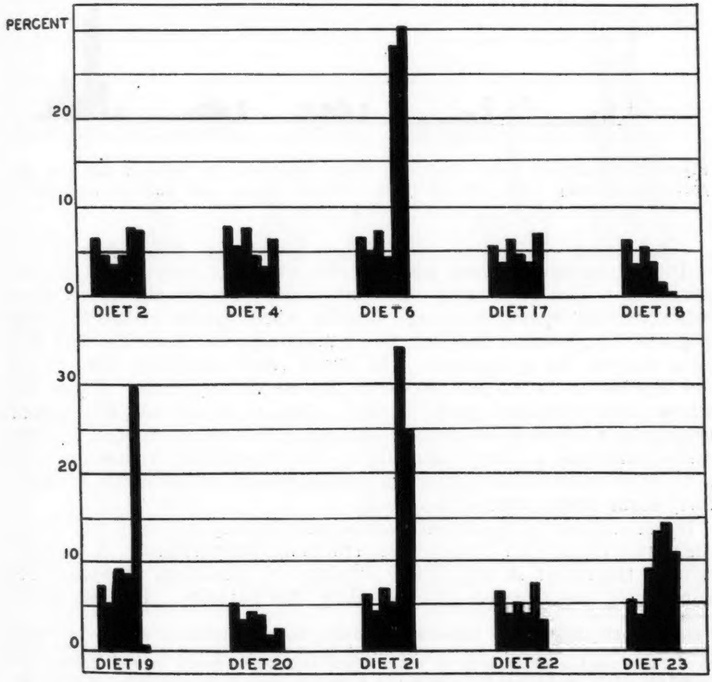


**Figure 4.—Brook trout mortality. Bars represent per cent of fish lost each period numbering from left to right. Period 2 was just half as long as the other periods.**

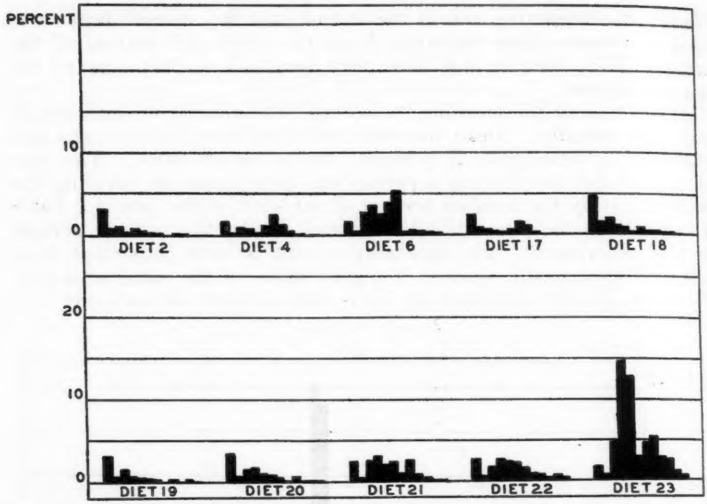


Figure 5.—Rainbow trout mortality. Bars represent per cent of fish lost each period numbering from left to right. Period 2 was just half as long as the other periods.

Disease caused a great part of the mortality throughout the experiment. The occurrence of ulcer disease among the brook trout was somewhat sporadic, though usually when one lot of fish receiving a given diet became infected the remaining lots receiving that diet soon showed the symptoms. The brook trout receiving Diet 18 did not appear to be subject to ulcer disease at any time. Those fish whose diets contained pork "melts" (Nos. 6, 21, 22 and 23) seemed unable to withstand the disease—in nearly every lot on each of these diets there was a heavy mortality.[4] Thirty-minute treatments with a 1:75,000 solution of potassium permanganate at intervals of about forty-eight hours were of no avail.

*Gyrodactylus* sp. occurred occasionally among the fish, but at no time was it allowed to grow to epidemic proportions. A twenty-minute treatment in a 1:75,000 solution of potassium permanganate apparently was effective in controlling this parasite. The use of the

[4]It would be unjust, however, without more complete evidence to blame the pork "melts" for this heavy mortality from ulcer disease since pork "melts" have been used successfully in trout diets and since many of the groups not receiving this food, notably those fed Diet 19, were also affected. It was unlikely that disease was spread from trough to trough since such precautionary measures as rinsing brushes and other implements used in handling the trout in strong solutions of potassium permanganate, copper sulfate or lysol were taken at all times.

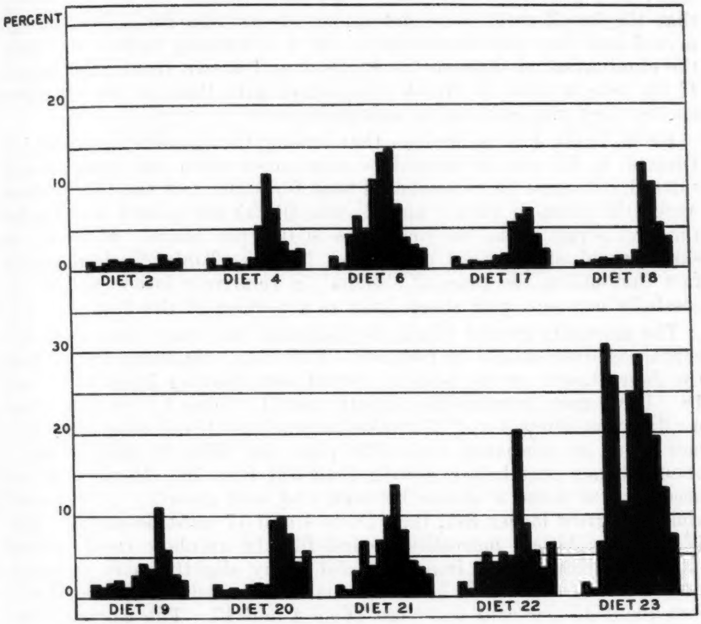


Figure 6.—Brown trout mortality. Bars represent per cent of fish lost each period numbering from left to right. Period 2 was just half as long as the other periods.

chemical had no visible harmful effect upon the trout, and probably did not materially affect the final results of the feeding experiment.

## Discussion

It would be unwise to attempt to evaluate definitely the various diets on the basis of the data presented here. Some of the combinations will bear further study before they can be recommended; others deserve further trial before being condemned. The tabular data probably portray better than words the results of the experiment. However, in conclusion a few statements are warranted regarding the relative value of the diets employed in this study.

Perhaps the most logical approach in selecting the best diets in this study is to eliminate at once all those diets which show the least promise of rearing fish at low cost. The diets which survive this elimination should be studied further in their relation to the mor-

tality and growth of the trout. We shall assume for the time being that the brook trout were not under observation for a long enough period and that the ulcer disease was a disturbing factor, and begin the elimination of diets in the rainbow and brown trout experiments. If the results with the brook trout agree with those of the other two species they may perhaps be acceptable also.

From Table 4 it is obvious that among the rainbow trout all but Diets 4, 6, 17, and 18 should be eliminated when cost alone is considered. It must be remembered that for sixteen of the twenty-three weeks the price of pork "melts" was $0.055 per pound whereas for the first seven weeks the price was $0.035 per pound. However, an examination of the food conversion factors (Table 2) discloses the fact that unless the price of "melts" is relatively low it cannot successfully compete with sheep liver as a portion of the diet.

The mortality record (Table 5) indicates that only those diets that contained liver should be retained. This then eliminates Diet 6 from the four chosen on the basis of lowest cost, leaving Diets 4, 17, and 18. If we now examine the growth record (Table 4) for these three we find that Diets 4 and 17 ranked second and third among the rainbow trout as compared with fifth place for Diet 18, and produced about 20 per cent better growth than did Diet 18. It now becomes necessary to make a choice between cost and growth. If the chief aim is to grow larger fish, then Diets 4 and 17 must be chosen. Diet 17 had the lowest mortality record for the rainbow trout, ranked second in growth, but fourth in cost (only slightly more expensive than Diet 4). Diet 18, however, enabled the fish to be reared at a cost about 15 per cent less than Diets 4 and 17. The mortality record of Diet 18 was low even though it ranked sixth; and the fish appeared in good condition.

Turning to the brown trout, from the standpoint of cost, Diets 2, 19, 20, and 23 can be eliminated immediately; the mortality record of Diet 6, ranking ninth, is somewhat high and this diet should therefore be eliminated also. However, Diet 6 yielded the best growth and was second lowest from the standpoint of cost. The high mortality on Diet 6 occurred during Periods 6, 7, and 8 (Table 5) and then receded.[5] Diets 4 and 17 are not far behind Diet 6 in cost and growth and both have very low mortality records. Diets 4 and 17 can be recommended from the standpoint of low mortality and good growth and Diet 18 from the standpoint of low mortality and low cost. Diet 6 was effective in producing good growth of brown trout at a low

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[5]When evaluating a diet in terms of the mortality of the trout that received the diet, one must consider the age of the trout at the time the mortality occurred. Obviously, the longer a trout has been confined and fed the greater is the loss in dollars and cents when death ensues. Early mortality, therefore, does not entail as large a financial loss as late mortality. From the data obtained during this experiment it is hoped that an equation for evaluating mortality may be derived, which considers the total cost of the trout at the time of death.

TABLE 5. MORTALITY IN PER CENT LOST DURING EACH TWO-WEEK PERIOD

| Diet No. | Period 1 | 2[1] | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Average Four periods | Average Twelve periods[2] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Brook Trout** | | | | | | | | | | | | | | |
| 2 | 6.55 | 4.83 | 3.60 | 4.62 | 7.62 | 7.43 | ...... | ...... | ...... | ...... | ...... | ...... | 4.90 | 5.78 |
| 4 | 7.99 | 5.73 | 7.53 | 4.79 | 3.30 | 6.31 | ...... | ...... | ...... | ...... | ...... | ...... | 6.51 | 5.94 |
| 6 | 6.63 | 5.13 | 7.26 | 4.58 | 28.21 | 30.50[3] | ...... | ...... | ...... | ...... | ...... | ...... | 5.90 | 13.72 |
| 17 | 5.59 | 3.81 | 6.24 | 4.72 | 3.92 | 7.15 | ...... | ...... | ...... | ...... | ...... | ...... | 5.09 | 5.24 |
| 18 | 6.13 | 3.54 | 5.54 | 3.86 | 1.44 | 0.63 | ...... | ...... | ...... | ...... | ...... | ...... | 4.77 | 3.52 |
| 19 | 7.32 | 5.33 | 9.11 | 8.91 | 20.93 | 0.73[3] | ...... | ...... | ...... | ...... | ...... | ...... | 7.67 | 8.72 |
| 20 | 5.27 | 3.47 | 4.32 | 3.99 | 1.84 | 2.43 | ...... | ...... | ...... | ...... | ...... | ...... | 4.26 | 3.55 |
| 21 | 6.14 | 4.47 | 6.95 | 5.49 | 34.36 | 25.00[3] | ...... | ...... | ...... | ...... | ...... | ...... | 5.76 | 13.73 |
| 22 | 6.68 | 4.06 | 5.37 | 4.17 | 7.65 | 3.29 | ...... | ...... | ...... | ...... | ...... | ...... | 5.07 | 5.20 |
| 23 | 5.74 | 3.94 | 9.11 | 13.40 | 14.53 | 11.04 | ...... | ...... | ...... | ...... | ...... | ...... | 8.05 | 9.63 |
| Average | 6.40 | 4.43 | 6.50 | 5.85 | 12.38 | 9.45 | ...... | ...... | ...... | ...... | ...... | | 5.80 | 7.50 |
| **Rainbow Trout** | | | | | | | | | | | | | | |
| 2 | 3.19 | 0.89 | 1.02 | 0.45 | 0.84 | 0.56 | 0.31 | 0.25 | 0.06 | 0.25 | 0.19 | 0.00 | 1.39 | 0.67 |
| 4 | 1.64 | 0.28 | 0.95 | 0.92 | 0.48 | 1.10 | 2.37 | 1.19 | 0.47 | 0.21 | 0.05 | 0.00 | 0.95 | 0.81 |
| 6 | 1.44 | 0.29 | 2.59 | 3.29 | 2.43 | 3.71 | 5.20 | 0.42 | 0.50 | 0.37 | 0.14 | 0.09 | 1.90 | 1.71 |
| 17 | 2.26 | 0.87 | 0.71 | 0.47 | 0.27 | 0.58 | 1.42 | 0.94 | 0.11 | 0.00 | 0.00 | 0.00 | 1.08 | 0.64 |
| 18 | 4.52 | 1.54 | 1.84 | 0.90 | 0.60 | 0.25 | 0.52 | 0.24 | 0.24 | 0.19 | 0.19 | 0.00 | 2.20 | 0.92 |
| 19 | 3.19 | 0.74 | 1.55 | 0.75 | 0.61 | 0.51 | 0.28 | 0.04 | 0.20 | 0.00 | 0.05 | 0.00 | 1.56 | 0.66 |
| 20 | 3.23 | 0.62 | 1.35 | 1.50 | 0.98 | 0.86 | 0.38 | 0.19 | 0.38 | 0.05 | 0.05 | 0.00 | 1.68 | 0.80 |
| 21 | 2.21 | 0.34 | 2.30 | 2.91 | 2.02 | 2.18 | 1.01 | 2.35 | 0.86 | 0.32 | 0.18 | 0.18 | 1.94 | 1.41 |
| 22 | 2.55 | 0.59 | 1.61 | 2.58 | 2.27 | 2.25 | 1.59 | 0.89 | 0.69 | 0.35 | 0.43 | 0.31 | 1.83 | 1.34 |
| 23 | 1.55 | 0.57 | 4.69 | 14.67 | 12.57 | 2.91 | 4.50 | 5.06 | 2.74 | 2.45 | 1.09 | 0.61 | 5.37 | 4.45 |
| Average | 2.56 | 0.67 | 1.87 | 2.84 | 2.16 | 1.42 | 1.79 | 1.11 | 0.63 | 0.42 | 0.24 | 0.12 | 1.99 | 1.32 |
| **Brown Trout** | | | | | | | | | | | | | | |
| 2 | 1.00 | 0.42 | 0.80 | 1.17 | 1.03 | 1.24 | 0.83 | 0.52 | 0.73 | 1.97 | 1.12 | 1.16 | 0.85 | 1.00 |
| 4 | 1.29 | 0.46 | 1.10 | 0.77 | 0.73 | 1.38 | 5.12 | 11.45 | 7.21 | 3.26 | 2.16 | 2.38 | 0.91 | 3.11 |
| 6 | 1.41 | 0.67 | 4.16 | 6.27 | 4.69 | 10.66 | 14.08 | 14.62 | 7.87 | 3.92 | 2.96 | 2.51 | 3.13 | 6.15 |
| 17 | 1.21 | 0.27 | 0.90 | 0.87 | 0.89 | 1.41 | 1.82 | 5.58 | 6.49 | 7.05 | 4.07 | 2.24 | 0.81 | 2.73 |
| 18 | 0.86 | 0.54 | 0.98 | 1.19 | 1.06 | 1.33 | 0.89 | 2.06 | 12.76 | 10.24 | 5.49 | 3.82 | 0.89 | 3.43 |
| 19 | 1.53 | 1.32 | 1.60 | 1.94 | 1.18 | 2.57 | 4.04 | 3.58 | 10.90 | 5.86 | 2.64 | 2.04 | 1.60 | 3.27 |
| 20 | 1.23 | 0.61 | 0.97 | 0.98 | 1.34 | 1.53 | 1.52 | 9.37 | 9.63 | 7.89 | 4.17 | 5.51 | 0.95 | 3.73 |
| 21 | 1.20 | 0.88 | 3.09 | 6.72 | 3.81 | 6.94 | 9.76 | 13.52 | 8.08 | 4.53 | 3.55 | 2.61 | 2.97 | 5.39 |
| 22 | 1.63 | 0.76 | 4.09 | 5.27 | 4.06 | 5.26 | 4.83 | 20.11 | 8.95 | 5.40 | 3.34 | 6.34 | 2.94 | 5.83 |
| 23 | 1.27 | 0.74 | 6.42 | 30.71 | 26.75 | 11.31 | 24.95 | 29.24 | 22.00 | 19.22 | 13.07 | 7.44 | 9.79 | 16.09 |
| Average | 1.26 | 0.65 | 2.41 | 5.59 | 4.55 | 4.36 | 6.78 | 11.01 | 9.46 | 6.93 | 4.26 | 3.60 | 2.46 | 5.07 |

[1]Period 2 is only one week long; other periods are two weeks.
[2]Only six periods for brook trout.
[3]These figures based on the mortality of only two troughs on each of the three diets; the mortality had been so heavy among the fish in the other two troughs that too small a number of fish was left to feed satisfactorily.

cost, but this good growth was accompanied by relatively high mortality.

Trout can be reared more cheaply, and with a mortality record almost as low, on Diets 4, 6, 17, and 18 than on the sheep liver diet fed to the controls (Diet 2). In general, trout reared on sheep liver present excellent growth and low mortality records, but the cost of this diet is about twice that of the other satisfactory diets.

Results of the rainbow and brown trout experiments are comparable to those with the brook trout in that Diet 18 again provided low cost fish, this time occupying third place. Diet 18 was associated with the lowest mortality record, Diet 20 running a very close second. Although Diet 6 provided good growth at low cost, its high mortality record disqualifies it.

It is concluded on the basis of this study that the diets containing pork "melts" are least desirable because of the heavy mortality. Unless the price of "melts" is relatively low, the cost to rear a pound of trout on diets that contain "melts" will not compare favorably with that of the diets that contain sheep liver. Diet 18 was outstanding when cost to rear trout was considered; Diets 4 and 17 were best when low mortality and good growth accompanied by relatively low cost were desired; and Diet 6 produced good growth at low cost in the brown trout, but was accompanied by rather high mortality.

## Acknowledgments

The author wishes to express his thanks to Mr. F. A. Westerman, Mr. A. B. Cook, Jr., and Dr. A. S. Hazzard, of the Michigan Department of Conservation; to Professor J. W. Stack, Dr. C. A. Hoppert, and Dr. P. J. Schaible of Michigan State College; and to Mr. Jay G. Marks, Mr. Wayne Gilmore, Mr. Royal Howe, and other members of the Wolf Lake hatchery for valuable guidance and assistance throughout the course of the experiments.

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## Discussion

Acting Chairman Foster: We would like to have some discussion of this paper.

Dr. A. S. Hazzard: Your conclusion, then, with regard to these supplements as compared with the straight meat diet, is that you can raise fish cheaper using the supplements, but you can not get as rapid growth as you can by using the straight meat. In other words, if the object is to raise the largest number of large-sized fish without any regard to cost in the shortest time possible, you would use the straight meat diet. Is that correct?

Mr. Wilkinson: Yes.

Dr. Hazzard: On the other hand, if the object is to raise as many trout as possible to a moderate size, the supplements will give you cheaper fish.

Mr. Wilkinson: That is borne out by the work we have done so far. In a few cases there has been work done in which larger trout are grown on diets consisting of fresh meats supplemented with meals. We found that the meat-fed fish, those that received the liver alone, grew to larger size in the same length of time. However, I think in some instances it has been found that those fish raised on meat diets supplemented with a certain amount of dry meal have grown to a larger size than meat-fed fish.

Acting Chairman Foster: On combinations containing dried food did you feed the fish all they would eat?

Mr. Wilkinson: We tried to follow regular hatchery routine through the tests. We allowed the fish all the food they would eat at any one feeding. If the hatchery men were feeding three times a day we fed our fish three times a day, and if they fed two times a day we fed ours twice a day.

This food, by the way, when it is put up in this fashion, is quite a sticky mess, and we simply put it in the trough in chunks and allow the fish to come up and nibble at it. They soon learned to eat that way, and although some men will object to that method and say perhaps the individuals don't get a very good chance at the food, that the smaller fish are prevented from getting a good meal because of the larger fish getting all the food they need, I think perhaps if they would observe the fish as we feed them they would see that that is not the case. The way this food is scattered along the trough, every individual apparently has an opportunity to get at it. I think one reason why there is rather an extreme range in size sometimes is the fact that when we do our "thinning" we remove the fish at random. We stir up the fish and take a sample out of the middle. We do our "thinning" when we weigh the fish. The hatchery man ordinarily will take fish from the foot of the trough, trying his best to sort them and to keep fish of equal size together. We don't follow that practice at all in this work.

Dr. J. S. Gutsell: I was interested in this feeding the fish with chunks. That is the way I found I had to do in order to avoid waste of the dry meal.

Mr. Wilkinson: We are quite satisfied with that method. It also avoids the waste, I think, of a good deal of the nutrient juice that is squeezed out of the

meat during grinding. Mixing the meat with the dry meal and allowing it to stand twelve to twenty-four hours before it is used gives the dry meal a chance to absorb the juices from the fresh meat, and I think there is very little loss from this method of feeding.

ACTING CHAIRMAN FOSTER: I would like to present at this time, in connection with that feeding method, the method that we have recently adopted in the West in the use of dried meals and in combination with liver in particular, or other moist products. We use principally liver; sometimes salmon viscera or spleen. In each instance the procedure is the same but the mixture, the combinations, may be slightly varied.

In beef liver and salmon carcass meal, which we make ourselves, we find the best mechanical mixture to be about 50-50. We mix that 50 per cent meal by weight and 50 per cent liver by weight together, either in a mechanical mixer or by hand, and then we put that through a blower which is direct-connected with an electric motor or belted from a gasoline motor. This blower revolves at 3,500 revolutions per minute, and if the "pre-mix" is done correctly and the correct percentage of dried food is mixed with the liver, it will come out not in gummy chunks, but as damp sawdust-appearing material which may be scattered readily. Then if that is left in a bucket for an hour or two to allow it to absorb even more of the juices, and run through the blower again, you get a still lighter product. It will not float on top of the water; it will scatter. It will not cloud the water and we found it far more satisfactory to feed.

The fish-culturists will run it through the blower as fast as they can feed it in. I hesitate to tell you the low amount of food necessary to produce a pound of fish. In some of our tests out there with salmon carcass meal and beef liver we have produced a pound of fish on less than a pound of the combination of 50 to 60 per cent salmon carcass meal and beef liver. Probably there will be some more papers out on that shortly.

Mr. Barker, have you seen that blower in operation?

MR. BARKER: No, I haven't seen it since the boys have set it up.

ACTING CHAIRMAN FOSTER: I don't believe anybody here has seen the blowers in operation in the East, although some have been sent to the East. In every station in the West where they have been tried the boys are very enthusiastic about them.

DR. DAVID SHETTER: I would like to ask you a question, Mr. Foster, with regard to the use of ground fish in general throughout the hatcheries that are near the two coastlines. The reason I ask is, I was presented with a little paper that Dr. Hile, of the Bureau of Fisheries, received from Sweden, and in it is mentioned the extensive use of waste fish in feeding trout. For the size of their trout hatcheries the production figures given are really phenomenal. I can't quote the figures, but I believe the paper is generally available for distribution. I would like to know what possible use there might be made of ground fish in the hatcheries near the coastlines.

ACTING CHAIRMAN FOSTER: I don't think it has been used as much as it should be used. I think Hayford has used it quite extensively.

During the last five months we have, at the University of Washington, in cooperation with the Bureau of Fisheries, conducted a series of experiments with salmon viscera, including "melts" and eggs, just as the viscera is taken from the fish. We have a conversion factor nearly equal to that of beef liver. The mortality is approximately the same and the health of the fish at the end of the five-months period is all that could be desired.

The fish were in a perfectly healthy condition. The losses during the five-months period on these Chinook salmon, which were the experimental animals, were around 4 to 5 per cent of the initial lot for the entire five-months period,

and we can buy salmon viscera on the coast at anywhere from one-half cent a pound to two and one-half cents a pound, depending on the firm from which it is purchased and the amount of time it is placed in refrigeration before it is used. All of the viscera was in refrigeration for in excess of six months before it was used in our experiments, so if the fish will go through five months in a healthy state under those conditions I think we can well explore the possibility of using fish waste to a greater extent than we are at the present time. We should hear from Dr. Davis on this question.

DR. H. S. DAVIS: So far as the fish are concerned, while we are still in somewhat of a quandary as to just what the situation is, there is a good deal of evidence to show that fresh fish which have not been frozen may give very different results from those frozen fish which have been kept in cold storage for some time.

Mr. Hayford, in the New Jersey hatchery, has several times run into difficulty there, apparently from feeding frozen fish. On the other hand, so far as we have been able to ascertain, a hatchery which feeds unfrozen fish, but fish which are in good condition, has had no difficulties in that respect. In one case in New Jersey when they lost a large number of fish, we found that the intestinal epithelium was entirely destroyed and the fish showed every evidence of being in intense pain. They would tear around the pond and leap 3 or 4 feet out on the bank. We stopped feeding the fish, and in a short time they recovered, and after we got them all straightened out we started feeding fish again, and they went through the same reactions. We are running some experiments now which we hope will give us further information in that connection.

There is one thing that is rather surprising, namely, that so many of these fellows conducting feeding experiments have so much difficulty in getting good growth on using the dried substances. We have a considerable number of diets. In fact, we feel that the ordinary straight meat diet gives comparatively mediocre growth as compared with some of the diets of dry products. That has been universally true in many of our experiments in the last two years, and I for one don't understand why others don't get better results than they do. I feel quite confident our results are reliable because they have been conducted at two stations where we have very different water conditions and with entirely different personnel, so the personnel factor can't enter into it.

ACTING CHAIRMAN FOSTER: I might say that my results on that parallel Dr. Davis' in the East. I have conducted these experiments with dried foods in at least five places in the West and invariably obtained a greater growth when supplementing the meats with the dried foods than was obtained by the use of straight meats. However, I want to express a word of caution on the use of the dried foods. Some of them are very powerful, and will burn up the fish if they are fed too great a percentage for too great a time. If care is not taken one will get into difficulty as sure as God made the little fishes. It is a thing the fish culturists have got to go easy on and not endeavor to take in the whole wide world when they first begin using such diets. They had better find out first what they can do at their own hatcheries in the matter of how extensively dried foods can be used before they can be adopted as a standard hatchery practice.

# CLUB-OPERATED FISH HATCHERIES—A PART OF INDIANA'S STATE-WIDE PLAN

C. R. GUTERMUTH

*Department of Conservation, Indianapolis, Indiana*

Indiana appreciates the opportunity to report to this Society the progress and accomplishments of its conservation clubs in fish production. This paper is neither scientific nor technical—it is more social in character and should be of interest to all of you. The propagation and rearing of native fish by conservation clubs was started several years ago in Indiana by a few organizations to supplement the restocking program of the State Department, and has since become indispensable. The club members wanted more fish in their streams and lakes; so they began rearing them. One or two of the clubs were fairly successful and from them the idea spread. As soon as the benefits of this work became apparent, fish culture was made more and more a club project. The Division of Fish and Game executed contracts with the clubs to pay them for the fish produced and distributed, and further incentive was unnecessary. When we offered to help defray expenses other clubs joined in the work so enthusiastically and with such whole-hearted support that their activities now exceed ours, and we supplement their efforts. Not only has production become a major factor in our fisheries program, but the interest of the clubs has extended to the creation of new fishing areas, the improvement of public waters, and the protection of our fish after they have been planted. In fact, club activities embrace almost every phase of conservation.

To understand the success of this program it is necessary that you know something of Indiana's conservation clubs. This state-wide movement dates back to 1933. At that time there were only thirty-seven clubs. Conservation was not receiving the attention that it is today. Indiana, like all of the other states, was having her problems, but it seemed that our greatest obstacle was public indifference. Practically everything we attempted was considered wrong, nothing was ever just right, and our good intentions were often misunderstood. After much deliberation we decided that an antagonistic, ill-informed or "wrong-minded" public would always be a hindrance and would continually offset all the good that the State Department could do to improve conditions.

So Indiana started out to eliminate "wrong-mindedness," through education and experience, particularly through experience, because that always brings enlightenment. We proceeded on the theory that no man would ever be a fish pirate or game hog once he had reared, cared for, and distributed game fish or game birds and animals. There may be exceptions, but we found that the rule generally

applies. We found that ninety-nine of every hundred violators will reform when they begin producing either fish or game for their home territory. The result is better fishing and hunting for everyone.

Most men are just men after all, and most of them have the same general attitudes. They all have the same impulses and these include the impulse to kill things, including fish. The difference between the outlaw and the sportsman is that the sportsman does his killing in moderation, according to accepted rules. To him the method of killing is everything. The violator has the same impulse to kill fish, but does not discriminate as to method. All this may not apply to your fishermen; nevertheless it did apply to ours. There was a wholesale disregard for fish and game laws and unfortunately, where fish pirates thrive, conservation does not exist. We were convinced that the situation could be corrected if we won the confidence of the people. Accordingly, we sought their support and cooperation by forming local conservation organizations.

Today there are 812 conservation clubs in Indiana. We have an active organization in every community large enough for one to function. There are clubs in all of our ninety-two counties. One county has twenty-six. Every class of sportsman, every circle of outdoorsmen, every group or sub-group interested in a more extensive conservation program is represented in the membership. They are working at conservation, teaching conservation, and are publicizing conservation affairs through 400 local newspapers. The women and children are thinking conservation, and are members of clubs or have their own auxiliary units. All of these organizations are conservation clubs in the truest and broadest sense; they are not merely social groups that meet monthly to "heckle" every constructive suggestion. If you don't think these Hoosiers are active in conservation come over and meet with some of the clubs. We keep six field representatives occupied full time working with the clubs and contacting the schools. These men attended 658 meetings last year, speaking to 197,173 people—to say nothing of the meetings attended by our game warden force, and the other members of the department. Come anytime; many of the men here in the room have been there and the clubs enjoyed their remarks about the work in other states. Although these organizations are interested mainly in local matters, they also keep in touch with national affairs.

The clubs are individual in character, although they are all affiliated in a state-wide organization. Each local unit elects its own club delegate. The club delegates meet once each month in a county council with a county representative presiding. The county representatives, elected by the club delegates, serve for two years. At a stated time these county representatives meet by conservation districts, of which there are sixteen, and elect district representatives, who also serve for two years. The district representatives make up what is known as the State Conservation Advisory Committee which

meets with the State Conservation Department four times each year. From these meetings, as from the county meetings, come splendid suggestions and recommendations for improvement. The state program is discussed and views are expounded. In recent years, no major policy has been adopted by the State Department without the approval of the clubs through their duly elected representatives. We could give you hundreds of illustrations as to how this plan has worked, such as the reaction of the legislature on bills presented bearing the approval of the clubs, but we will be brief.

The fish hatchery program is fitted into this state-wide organization as merely one club activity. We are sorry that time does not permit the explanation of other club projects such as the removal of coarse and predacious fish from our lakes and streams, reforestation, winter feeding, and game propagation. For example, 579 clubs have contracts with the Department this year for the hatching and rearing of pheasants and quail, 151 of these clubs own and operate approved electric brooders for the handling of day-old chicks hatched at the state game farms. If this were not a fisheries meeting we would go into some of these matters, but let's talk about fish.

The majority of our club hatcheries have been built with federal assistance. The clubs provided the materials and the W. P. A. furnished the labor. The sites are either rented, leased or purchased. Where the land is bought it is deeded over to the state, county or municipality. If it is leased, a long-term public dedication must be signed, and if it is rented, the rental agreement must be submitted to the State Department, which insists that the club receive a fair percentage of the funds received under our contract. Generally, after the first year the club sees the advantage of owning its own acreage. This frequently means the purchase of a sub-marginal farm, which is converted into a club headquarters, very often including a club house, picnic area, rifle range, skeet and trap grounds, fish ponds, raccoon pens and a game propagation field with electric brooders.

A few of the clubs have seen fit to restrict the use of their properties to club members and their families. These clubs cannot obtain federal aid but must finance the entire project out of club funds. The members, themselves, do the work. In any event, the fish hatchery sites ordinarily become a sort of community park. People take picnic suppers to the hatchery grounds, preparing their meals on outdoor ovens provided for that purpose. Wives and children learn to distinguish a bass from a bluegill, and smallmouth fingerlings from largemouth. They hear the discussions on fish culture and the reasons for it. Thus the spirit and knowledge of conservation are extended outside the club membership.

One of Indiana's clubs has won two first awards in the National Fish Production contest sponsored by the Izaak Walton League of America. Another year it won second place. It was this club that pioneered in fish production and it is still a leader in this

work. Several of the clubs have artificial lakes on their grounds that provide splendid fishing. Two of the clubs located in larger cities operate public bathing beaches at their club properties where complete facilities are available, including life guard service. The income from these projects, above expenses, is used to carry on conservation activities of a permanent nature.

Several of the clubs have been very successful in the rearing of trout. We have some good trout fishing in Indiana and it improves each year. Fingerlings of from 1 to 2 inches are obtained from the U. S. Bureau of Fisheries, transported into Indiana in the Department's trucks, and held in the club ponds until fall.

It is in the north and central parts of the state that fish production by clubs has had its greatest development. In those sections the ponds are not limited as to size. However, most of them are under 3 acres. Clear streams and large springs provide such an abundance of water that the clubs can and do have more than one pond.

In southern Indiana we have entirely different natural conditions. There the limestone sinks make pond construction difficult or impossible. There, also, are the larger fish, the 100-pound catfish and the muskellunge. The attitude toward small game fish was not the same as that in the north, but it is changing very rapidly due to the many lakes built by the W. P. A. All of these lakes are heavily stocked and opened to public fishing. Many a man who formerly sought only channel catfish or suckers now angles for bluegills, crappies, rock bass, and largemouth bass. This spring a 9-acre lake in Brown County was opened for the first time, and it might interest you to know that over four hundred of the former stream fishermen were on hand at midnight to try their luck in this small lake. Lake fishing is entirely new to some of these people. However, they see the results of fish planting, and quite naturally, the idea of club production has moved southward in the state until today there are a number of southern counties where you will find one or more clubs operating ponds. They search for suitable locations, call in our geologist, engineers, and our fish hatchery technician for advice, and submit their project for federal approval. They must depend largely on surface water for their water supply, but this problem has caused little trouble.

The clubs have been very eager to accept advice and follow instructions in the operation of their hatchery ponds. At first we had a little trouble persuading clubs to use enough fertilizer. Some were prone to overload the ponds with parent fish; others were bothered with pond seepage; and still others found the water temperature a trifle too cold for warm-water species. All of these difficulties were soon corrected. All in all, the clubs have had few setbacks and their losses from disease or parasites have been negligible.

Most of the hatchery sites include a *Daphnia* tank, and a large percentage of the club hatchery men are becoming proficient in the

use of soy-bean meal as a food. These men do not have a microscope and probably could not use one if they had it. They look to us when difficulties arise. The clubs seem generally to go along without help, produce plenty of fish and make money.

The state does not execute fish agreements with individuals. All of the contracts issued for fish and game work are restricted to conservation clubs. With junior clubs we make a "half-contract" which means they receive only half of the total amount paid to senior clubs. At first, contracts were issued only to adult groups and were restricted to bass production. The schedule called for the payment of $30.00 per thousand for No. 3's, $40.00 per thousand for No. 4's, and $50.00 per thousand for No. 5's. The maximum payment allowed for the fish reared by one club, or in any one set of ponds, in one year is $500.00. After a couple of years the department found, that with the increased production, the rates were a little high, so they were reduced to $20.00 per thousand for No. 3's, $30.00 for No. 4's, and $40.00 for No. 5's.

At the time of this revision of rates other classifications and species were added to the contract to encourage the propagation of bluegills, rock bass, red-ears, and crappies. The rates on these species were necessarily different, and by the way, all we need to do to increase or decrease the production of any particular species, is to change the terms of the contract. At the present time the rate is $5.00 per thousand for bluegills, red-ears, and crappies of 1½ inches or longer, and $10.00 per thousand for rock bass of 1½ inches or longer. With these species, the rate is the same for all fish regardless of length, but the fingerlings must be at least 1½ inches long to receive settlement under contract. Another important clause is that the State receives all the fish that do not come up to contract length.

The ponds are to be drained not later than October 20th. When distribution is made the actual planting is done by club members. However, a warden is on hand to count the fish and see that the plantings are made in accordance with the State's restocking program. The report of the Department representative must check with the report of the club before payment is made for the fish.

In 1934 we thought that the state hatcheries could supply the fry to stock club-rearing ponds. We were sadly in error. At that time we estimated that, with a little encouragement, there might be eighteen clubs that would raise fish, but to the astonishment of everybody, these figures were reversed and eighty-one clubs made contracts and received fry.

In 1935 the offer to supply fry was withdrawn and the clubs were required to furnish their own parent stock, produce the fry and rear them to contract size. The club members did not complain. They themselves fished with hook and line, filled the ponds with parent fish and enjoyed the work. In that year the Department

issued a booklet designed to help the clubs in building ponds, obtaining fish, producing the fry and rearing the young.

Where help was needed the game wardens won many friends by assisting the clubs in the management of their ponds. They also helped in the capture of parent fish by organizing fishing parties in the spring. Careful arrangements were made to care for the fish and give them salt treatment before placing them in the ponds. On a number of occasions the wardens used nets or seines to take parent stock, but did so only in extreme emergencies.

Fishing actually does improve in the vicinity of club-operated hatcheries. The improvement may be traced to two factors—the new interest in the welfare of lakes and streams, and the increased stocking. There is no doubt about the improvement; the fishermen are constantly reporting it and commenting on it.

Last year (1937) 121 clubs received payment for fish and a number of these received the limit of $500.00. Some of them can be counted on year in and year out to produce the limit in smallmouth bass alone, and the fingerlings will be from 5 to 8 inches long. During 1937 the clubs reared and planted 3,608,219 fingerlings of various species. One county produced over a million bluegills of contract size, not to mention the hundreds of thousands that were too small to count.

This year 182 clubs have contracts and several others have ponds under construction. Today Indiana has 434 club-operated ponds, with an aggregate of 264½ acres of water under contract with the State Department. In one county alone there is more water area in club-operated ponds than in all of the state-owned fish hatchery ponds combined.

The idea continues to grow and with the growth we have a visible permanent improvement. Fish production by clubs is but a small part of the state program. It is succeeding just as the entire club program has succeeded for over four years. Organized conservation is established so firmly in Indiana that it will always be a dominant and forceful influence in the social and economic life of our State.

## Discussion

Acting Chairman Foster: Mr. Gutermuth, your paper has been of particular interest to the Chairman. As some of the older members in the room will recall, early in the 1920's—in 1922, I think—when the meeting was held in St. Louis, Missouri, I presented a paper entitled, "The Sportsmen's Club an Undeveloped Power in Conservation." If we lag behind in our hatchery development, as brought out by Dr. Davis' paper, I don't think we have lagged behind with the sportsmen's clubs as a powerful force in conservation.

To show that the development is not entirely east of the Mississippi River, I am pleased to tell you that at this time a hatchery is being constructed in northern Idaho near Wallace, a sparsely settled mining community, where the sportsmen have raised, through devious means, over $20,000 to pay for the materials to go into the hatchery. They are going to have a fine hatchery with

an experienced fish culturist to be supplied by the Bureau of Fisheries to operate it.

MR. A. D. ALDRICH: I would like to verify the statements of the last speaker in regard to public sentiment. I think the important thing is to make fish managers out of our sportsmen. We have been talking back and forth among ourselves for years, but we haven't been saying very much about the angler himself. I think it has been pointed out in Indiana that the interest of anglers will make for better fishermen as well as for better fishing, and our products, our fish, will be benefited.

If we can make good sportsmen out of our fishermen, as we have tried to do in Tulsa where a great many go fishing merely for the sport and catch fish and release them, I believe that we have a more economical program than if we attempt to supply three or four times as many fish. If four people catch the same fish it has the same result as planting four times as many fish.

MR. T. C. FEARNOW: May I ask how much supervision the State Fisheries Department gives to the trout nurseries?

MR. GUTERMUTH: We have one well experienced man who is in charge of this work. This man was formerly our Superintendent of State Fish Hatcheries, and he devotes all of his attention to these clubs now. I might say that we have had very little trouble. The clubs have come to us, of course, before they have attempted to construct their ponds, and through the advice that we have been able to give them and the little booklet that I mentioned we have had very little, if any, trouble, in any of our club hatcheries.

MR. FEARNOW: My reason for asking this question is that down in West Virginia I was in contact with a similar development back in 1928 and 1929, and the chief difficulty we experienced was from outbreaks of disease. I was called out at all hours of the day and night to fight diseases in some club rearing pool back in the mountains.

MR. GUTERMUTH: I might mention one thing. In southern Indiana, as I explained, some of the clubs got into difficulties. They employ surface water to a large degree for their water supply, and rather frequently we had calls from clubs, as you mentioned, in the middle of the night. We found in some instances that it was mine waste or some other pollution coming in with the surface water that was killing the fish. In practically all of those hatcheries they have employed the use of a filter, perhaps a gravel dam in the source of their water, which eliminated most of the trouble.

DR. GUSTAVE PREVOST: I may say that in the Province of Quebec we tried to give fry to the clubs, but we didn't have much success with the program. Sometimes diseases broke out, and a number of clubs abandoned the project of rearing the fish. They like better to buy the fish from our own hatcheries. They say it is cheaper than to rear their own fish.

ACTING CHAIRMAN FOSTER: I think it is a local problem and usually one of proper supervision. I believe, however, that members of this Society can do a world of service to the Society, to the sportsmen's organizations, and to conservation in general, by endeavoring to secure the membership of such organizations in this Society. Many of these clubs would wish to receive the Transactions if their attention was called to them. They could devote one meeting to the reading and discussion of a paper, and thus receive many times the value of the $5 which is the required membership fee for a sportsmen's organization.

I am going to leave that thought with you for the next meeting in San Francisco. Let's have a lot of sportsmen's applications brought in by the members that are present at the next meeting.

THE SECRETARY: It is not proper for anybody at this desk to speak, excluding the Chairman, but having for ten years been in the national conservation field and having worked primarily with organized groups in conjunction with our various administrators, I may say that this is one of the types of activity which I have always sponsored and encouraged. I honestly believe that a great many of us have been thinking too much of operating our own machinery instead of getting a lot of other people to help sand the tracks and grease the wheels.

Club activity provides not only a way to produce more fish, but it is a big educational undertaking which is certain to pay real dividends. The more the leaders of sportsmen's groups learn how difficult it really is to provide good hunting and good fishing, the more they are going to appreciate the problems of their state administrators and the more they are going to be sympathetic and cooperative. I have felt for a long time that too frequently we hesitate to take sportsmen's groups into co-partnership for fear they would ultimately want to run the show. I really believe that by giving the kind of supervision which local groups need they can, with a considerably smaller expenditure on the part of the central agency, produce many more fish and at the same time produce many more of the kind of fishermen we need. I only wish that this paper might have been presented at the International Association instead of before the Fisheries Society—not that we don't need it. We need it in our own group right here, among those of us who are in fish culture and fish management—but unfortunately not all of the several states are in this group. I do hope that when this paper is published in the Transactions all of the officials, at least those interested in fisheries problems, will take time to read it. Probably some of those who are interested in the production of game for stocking purposes will also take time to read it.

# FERTILIZERS FOR INCREASING THE NATURAL FOOD FOR FISH IN PONDS[1]

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**ABSTRACT**

**Experiments using commercial fertilizer in distilled water indicated that an N—P—K—$CaCO_3$ ratio of 4:1:1:8 gave most economical plankton production. Pond waters in Central Alabama were found to require the addition of nitrogen, phosphorus, potash, and lime for maximum fish and plankton production. For use in pond waters, the above ratio was used with the amount of phosphorus doubled, giving a 4:2:1:8 ratio of N—P—K—$CaCO_3$. The application of this mixture of commercial fertilizers gave a fish production of 578 pounds per acre, compared to 134 pounds per acre in the unfertilized control.**

**The amounts of commercial fertilizers used at present per acre per application are:**

**40 pounds sulfate of ammonia**
**60 pounds superphosphate (16 per cent)**
**5 pounds muriate of potash**
**30 pounds basic slag (or 15 pounds $CaCO_3$)**

**Experiments are still in progress to determine if smaller applications can be used successfully.**

## INTRODUCTION

The results of the authors' work reported at this meeting in another paper demonstrated a direct relationship between the average plankton content of pond waters and fish production. The establishment of this fact by experimental methods enables the results of fertilizer experiments to be stated in terms of the amount of plankton producd as well as in terms of the pounds of fish produced per acre. The experiments discussed in this paper consist of tests conducted both in a greenhouse and in ponds to determine the composition of fertilizers required for the most efficient production of plankton, and of tests in various sized ponds and concrete pools to determine the effect of these fertilizers on the production of both plankton and fish.

For efficient production of plankton it is necessary to supply the various fertilizer elements in such proportion that all will be completely utilized by the phytoplankton. Any material added in excess of that utilized merely adds to the cost of fertilization and tends to accumulate in pond waters. The statement is often made that the fertilizers found necessary for use on farm soil in a particular region should be the most suitable for use in the pond waters of that region. However, for land crops, the fertilizer is applied to the soil, and the soil has a very important effect upon the fertilizer. It acts in part as a temporary storehouse for the fertilizer elements

[1]Published with the approval of the Director, Alabama Agricultural Experiment Station.

and gives up the elements of fertility slowly to the roots of plants. In addition, it reacts more or less rapidly with the phosphates and converts them into a relatively insoluble form not readily available to plants. Consequently, heavy applications of fertilizer may be made and a considerable excess of phosphate over that actually utilized must be added. Where fertilizers are applied to pond waters, all the soluble material is at once available to the phytoplankton, and unless the water contains suspended soil colloids, or considerable soluble iron, the phosphate is tied up in unavailable form only as it comes in contact with the soil on the sides and bottom of the pond. Thus smaller applications must be made to ponds than to soils and less phosphate should be required.

## Greenhouse Experiments

In order to determine the correct ratios of the various fertilizer elements for plankton production, experiments were set up in a greenhouse, using distilled water in glass jars of a capacity of 4 liters. The nutritive elements were supplied by various commercial fertilizers. Each jar was then inoculated with the same volume of a concentrated plankton culture, and allowed to stand in the greenhouse. When the culture approached maximum growth, several samples were taken at weekly intervals and the amount of plankton determined by centrifuging, drying, and then incinerating the dried sample, using the method described by Juday (1926). At the same time water samples were taken for chemical analysis. The amounts of nitrogen and phosphorus reported in Table 1 were determined according to the methods described by Morgan (1937). The ammonia and nitrate nitrogen (Table 2) were determined by the methods advocated by the Association of Official Agricultural Chemists (A.O.A.C.) (1924) for water analysis, and the phosphate by the method described by Truog (1930). The pH values in all tests were determined with the glass electrode.

**TABLE 1. RESULTS OF NITROGEN-PHOSPHORUS RATIOS FOR PLANKTON PRODUCTION[1]**

| Ratios in p.p.m. of elements N[2] : P : K | pH Initial | pH Final | Average plankton production (milligrams per liter) | P.p.m. residual[3] N | P.p.m. residual[3] P |
|---|---|---|---|---|---|
| 0 : 2 : 10 | 5.8 | 5.6 | 4.7 | 0.2 | 1.8 |
| 1 : 2 : 10 | 6.0 | 5.2 | 16.6 | 0.5 | 1.8 |
| 2 : 2 : 10 | 5.9 | 5.0 | 20.9 | 0.5 | 2.0 |
| 4 : 2 : 10 | 6.0 | 4.4 | 40.1 | 0.5 | 1.3 |
| 6 : 2 : 10 | 6.1 | 4.1 | 37.7 | 0.9 | 0.8 |
| 8 : 2 : 10 | 6.0 | 4.0 | 34.6 | 1.3 | 0.3 |
| 10 : 2 : 10 | 6.0 | 3.9 | 43.7 | 2.3 | 0.7 |
| 16 : 2 : 10 | 6.1 | 3.8 | 41.6 | 7.5 | 0.7 |

[1]The figures given are the averages of four separate tests.
[2]Nitrogen supplied by sulfate of ammonia.
[3]These analyses were made under the direction of G. D. Scarseth, using the method described by Morgan (1937).

TABLE 2. RESULTS OF NITROGEN-PHOSPHORUS RATIOS FOR PLANKTON PRODUCTION[1]

| Ratios in p.p.m. of elements | pH | | Average plankton production (milligrams per liter) | P.p.m. residual | |
|---|---|---|---|---|---|
| [2]N : P : K | Initial | Final | | N | P |
| 0 : 2 : 2 | 6.4 | 7.2 | 7.2 | 0.10 | 1.10 |
| 1 : 2 : 2 | 6.3 | 7.1 | 21.7 | 0.15 | 0.60 |
| 2 : 2 : 2 | 6.3 | 7.2 | 36.5 | 0.10 | 0.30 |
| 4 : 2 : 2 | 6.7 | 7.2 | 60.3 | 0.16 | 0.10 |
| 6 : 2 : 2 | 6.6 | 7.4 | 99.9 | 0.16 | 0.00 |
| 8 : 2 : 2 | 6.0 | 7.5 | 110.1 | 0.20 | 0.00 |
| 10 : 2 : 2 | 6.1 | 7.4 | 126.1 | 0.16 | 0.00 |
| 16 : 2 : 2 | 6.0 | 7.7 | 144.4 | 0.50 | 0.02 |

[1]The figures given are the averages of three tests.
[2]Nitrogen supplied by sodium nitrate.

The phytoplankton raised in these experiments consisted of a mixture of *Chlamydomonas, Chlorella, Scenedesmus, Ankistrodesmus, Oscillatoria,* and various diatoms.

## The Nitrogen-Phosphorus Ratio

In order to determine the correct ratio between nitrogen and phosphorus, the concentration of phosphorus, in the form of superphosphate (16 per cent), was held constant at 2 p.p.m. in one series and at 4 p.p.m. in another series. In each of these series the nitrogen, in the form of ammonium sulfate, was then varied from 0 to 16 p.p.m. In both series the potash, in the form of muriate of potash, was held at 10 p.p.m. in order that it might not be a limiting factor. In the second series, where 4 p.p.m. phosphorus were used, no increase in plankton production occurred over that which was secured in the first series with 2 p.p.m. phosphorus.

The results of the first series of experiments are given in Table 1. Plankton production increased with increase in nitrogen up to 4 p.p.m. of the element. Further increases in nitrogen did not increase the amount of plankton, apparently because of the excessive acidity produced in these cultures by the use of ammonium sulfate. The acidity of the cultures increased from pH 5.2 to 3.8 with increases in the concentration of ammonium sulfate.

The values given in Table 1 for residual amounts of nitrogen and phosphorus were determined by the methods of Morgan (1937). These methods appear to be insufficiently accurate for this type of investigation. However, the results indicate that nitrogen and phosphorus were being utilized at ratios of from 3:1 to 6:1 of the elements.

The above experiment was repeated using sodium nitrate as the source of nitrogen, and more accurate results were obtained through the use of A. O. A. C. methods of analyses (Table 2). Nitrogen and phosphorus were apparently utilized at ratios varying from approximately 3:1 to 8:1 of the elements. These results are essentially the

same as those found in the first experiment (Table 1). Plankton production increased with each increase in the amount of nitrogen used. Considerable variation was found in the ratio at which nitrogen and phosphorus are used by plankton. This variation was possibly due in part to the presence of several groups of plankton in each culture. When the results were averaged, the nitrogen-phosphorus ratio was between 4:1 and 5:1. Since considerable competition exists in pond waters for phosphorus, the 4:1 ratio was assumed to be the nearest correct for fertilizer mixtures.

### The Nitrogen-Phosphorus-Potash Ratio

To determine the amount of potash needed in plankton fertilizer, the same procedure and the same commercial fertilizers (with sulfate of ammonia as the source of nitrogen) were used as in the preceding experiment. In the first series of tests, 6 p.p.m nitrogen and 4 p.p.m. phosphorus were used in order to give a slight excess of these two elements. The potash was then varied from 0 to 8 p.p.m.

The results of these experiments are given in Table 3, and seem to indicate that some potash is necessary, but that an application of 2 p.p.m. of the element is sufficient. These results were then checked using a N — P — K mixture in the ratios of 8:2:10 and 8:2:2 p.p.m. There was practically no difference between the two rates of potash application in their effect on plankton production. The approximate nitrogen-phosphorus-potash ratio for the most efficient production of plankton therefore appears to be 4:1:1.

TABLE 3. THE POTASH-NITROGEN-PHOSPHORUS RATIO FOR PLANKTON PRODUCTION

| Ratios in p.p.m. of elements N : P : K | Plankton production (milligrams per liter) |
|---|---|
| 6 : 4 : 0 | 26.4 |
| 6 : 4 : 2 | 44.6 |
| 6 : 4 : 4 | 35.0 |
| 6 : 4 : 6 | 49.6 |
| 6 : 4 : 8 | 44.0 |

### The Lime-Nitrogen-Phosphorus-Potash Ratio

Where ammonium sulfate was used as the source of nitrogen, high acidity developed in the cultures as indicated by the results in Table 1. Since preliminary experiments in dirt pools had demonstrated that high acidity prevented the growth of zooplankton, and that under these conditions pond fish grew very poorly, it is evident that some material must be added to prevent the development of such acidity. The materials commonly used for this purpose on farm crops are basic slag, ground limestone, and dolomite. Since basic slag is more generally available throughout Alabama than the other two materials, its use was tested first. The alkalinity of basic slag is approximately equivalent to 50 per cent $CaCO_3$.

Decreases in acidity accompanied increases in concentration of slag from 0 to 64 p.p.m. of $CaCO_3$, and between 12 and 16 p.p.m. $CaCO_3$ were required to keep the reaction above pH 5.0 (Table 4). However, increases in the amount of slag above 12 p.p.m. $CaCO_3$ decreased plankton production.

Why this addition of larger amounts of slag decreased plankton growth is unknown. Decreased plankton production appeared to be correlated with decreased carbon dioxide in the water (Table 4).

**TABLE 4. NEUTRALIZATION BY THE USE OF BASIC SLAG OF THE ACIDITY DEVELOPED FROM AMMONIUM SULFATE IN PLANKTON CULTURES**

| Ratios in p.p.m. of | | | | pH | | Plankton production (milligrams per liter) | P.p.m. | | |
|---|---|---|---|---|---|---|---|---|---|
| N | P | K | $CaCO_3$ | Initial | Final | | $CO_2$ | $HCO_3$ | $CO_3$ |
| 6 | 4 | 2 | 0 | 6.3 | 4.3 | 32.0 | 0.0 | 0.0 | 0 |
| 6 | 4 | 2 | 2 | 6.6 | 4.4 | 35.0 | 0.0 | 0.0 | 0 |
| 6 | 4 | 2 | 4 | 6.8 | 4.5 | 32.4 | 14.3 | 6.1 | 0 |
| 6 | 4 | 2 | 8 | 7.2 | 4.6 | 36.4 | 18.7 | 6.1 | 0 |
| 6 | 4 | 2 | 12 | 7.3 | 4.9 | 54.0 | 14.3 | 9.2 | 0 |
| 6 | 4 | 2 | 16 | 7.5 | 5.3 | 37.4 | 11.0 | 21.4 | 0 |
| 6 | 4 | 2 | 24 | 7.9 | 5.6 | 33.0 | 6.6 | 18.3 | 0 |
| 6 | 4 | 2 | 32 | 8.0 | 5.6 | 32.4 | 4.4 | 24.4 | 0 |
| 6 | 4 | 2 | 64 | 8.3 | 6.7 | 26.4 | 0.0 | 18.3 | 6 |

It was thought that the slag interfered with plankton growth by tying up a part of the $CO_2$ so that it was not available for photosynthesis. If this were true, it appeared that the use of calcium carbonate would not present this difficulty, while the use of calcium hydroxide would be as bad, or worse, than the slag. The experiments reported in Table 5 were conducted to test this assumption. The results indicated that the application of large amounts of calcium carbonate also tended to decrease production slightly. Basic slag, however, decreased production to a much greater extent. Calcium hydroxide was more similar in action to calcium carbonate than to slag. It is possible that some material present in the slag exerts a toxic action on the plankton when used in large quantities. Basic

**TABLE 5. NEUTRALIZATION BY CALCIUM CARBONATE, SLAG, AND CALCIUM HYDROXIDE OF THE ACIDITY DEVELOPED FROM AMMONIUM SULFATE IN PLANKTON CULTURES**

| Ratios in p.p.m. of | | | | Source of lime | pH | | Plankton production (milligrams per liter) | P.p.m. | |
|---|---|---|---|---|---|---|---|---|---|
| N | P | K | $CaCO_3$ | | Initial | Final | | $CO_2$ | $HCO_3$ |
| 6 | 4 | 2 | 0 | $CaCO_3$ | 6.0 | 4.4 | 32.6 | 0 | 0 |
| 6 | 4 | 2 | 2 | $CaCO_3$ | 6.2 | 4.4 | 36.3 | 0 | 0 |
| 6 | 4 | 2 | 4 | $CaCO_3$ | 6.7 | 4.6 | 40.2 | 16.5 | 9.2 |
| 6 | 4 | 2 | 8 | $CaCO_3$ | 6.8 | 4.9 | 57.6 | 16.5 | 9.2 |
| 6 | 4 | 2 | 12 | $CaCO_3$ | 6.9 | 5.0 | 73.4 | 11.0 | 12.2 |
| 6 | 4 | 2 | 16 | $CaCO_3$ | 7.0 | 5.0 | 81.4 | 9.0 | 18.3 |
| 6 | 4 | 2 | 24 | $CaCO_3$ | 7.1 | 5.6 | 67.8 | 4.4 | 21.4 |
| 6 | 4 | 2 | 32 | $CaCO_3$ | 7.2 | 6.1 | 62.8 | 2.2 | 21.4 |
| 6 | 4 | 2 | 64 | $CaCO_3$ | 7.5 | 6.0 | 60.4 | 3.3 | 21.4 |
| 6 | 4 | 2 | 64 | Basic slag | 7.6 | 6.5 | 39.6 | 0 | 18.3 |
| 6 | 4 | 2 | 64 | $Ca(OH)_2$ | 8.0 | 6.8 | 64.4 | 2.2 | 27.5 |

slag and calcium carbonate were approximately equal in neutralizing action; it required 12 or more p.p.m. $CaCO_3$ to maintain the reaction at pH 5.0. Maximum plankton production occurred at a concentration of 16 p.p.m. $CaCO_3$. The ratio of N—P—K—$CaCO_3$ for plankton production apparently should be approximately 4:1:1:8, for in this proportion the materials are completely available to the phytoplankton.

## Fertilizer Tests in Ponds

While the above ratio of 4:1:1:8 gave good results in glass jars, there yet remained the task of determining whether the addition of nitrogen, phosphorus, potash, and lime were necessary in pond waters or whether these waters could be depended upon to supply all or part of these nutrients. It was also necessary to determine if the use of these materials increased fish production as well as plankton production, and to determine the most economical quantities to use per acre of water.

To determine the value of the addition of the various fertilizers, a series of experiments was conducted in dirt ponds having an area of one one-hundred-thirtieth acre and a uniform depth of 3 feet. These ponds were stocked with 100 fingerling bluegill bream (*Helioperca macrochira*) per pond on September 9 and drained on the following May 1. The total weights of fish produced represent the fall, winter and early spring growth. The fertilizer elements were added at a rate which provided the pond waters with 10 p.p.m. of the elements. Subsequent applications were made at approximately monthly intervals until the end of the experiment. The results are given in Table 6.

**TABLE 6. FERTILIZER TESTS AND PLANKTON AND FISH PRODUCTION IN SMALL PONDS, SEPTEMBER 9, 1935 TO MAY 1, 1936**

| Pond No. | Treatment | Average plankton production (milligrams per liter) | Fish production (pounds per acre) |
|---|---|---|---|
| 1 | None | 4.8 | 90 |
| 2 | Superphosphate | 3.5 | 134 |
| 3 | Superphosphate + $NaNO_3$ | 6.5 | 156 |
| 4 | Superphosphate + $(NH_4)_2SO_4$[1] | 11.7 | 174 |
| 5 | Superphosphate + $NaNO_3$ + KCl | 8.0 | 251 |
| 6 | Superphosphate + $NaNO_3$ + KCl + $CaCO_3$ | 24.4 | 330 |
| 7 | $NaNO_3$ | 4.5 | 79 |

[1]This pond developed excessive acidity.

These results support the statement made previously that fish production was correlated directly with plankton production, except when the third treatment (superphosphate plus ammonium sulfate) was used. The cause of the negative result appeared to be excessive acidity, for the reaction of the water in this pond varied in pH from 4.0 to 4.7 throughout the experiment. Under these conditions, a heavy plankton production does not result in heavy fish production, as was previously indicated.

It is apparent that the pond waters responded to applications of nitrogen, phosphorus, potash, and lime. Ammonia nitrogen was slightly superior to nitrate nitrogen from the standpoints of plankton production and fish production. The need for the addition of some material to prevent excess acidity was apparent. Such an agent was used in the following experiments and the treatment, ammonium sulfate plus superphosphate plus slag, produced 588 pounds of bluegill bream per acre. This was the best production obtained with any of the treatments used.

Chemical tests indicated that considerable quantities of phosphorus were being tied up in the dirt ponds. In testing the N—P—K—$CaCO_3$ ratios developed in the greenhouse experiments for their effect in ponds the amount of phosphorus therefore was doubled. The ratio 8:4:2:16 p.p.m. of N—P—K—$CaCO_3$ was used and applications were made at approximately monthly intervals to a pond having an area of approximately one-tenth acre, and averaging 3 feet deep. The pond was stocked with bluegill bream (*Helioperca macrochira*), red-eye smallmouth bass (*Micropterus* sp.), crappie (*Pomoxis annularis*), and catfish (*Ameiurus natalis*). This pond produced fish during the period April 2 to November 8, 1937, at the rate of 578 pounds per acre, while the unfertilized control pond produced these same species at the rate of 134 pounds per acre. There was, therefore, an increase of 330 per cent in fish production due to fertilization.

## Rate and Frequency of Application of the 8:4:2:16 (N—P—K—$CaCO_3$) Fertilizer

Experiments were conducted in concrete ponds during 1937 to determine the effect of various rates and frequencies of application of the mixed fertilizer to ponds. These ponds had a surface area of one-four-hundredth acre and were 2 feet deep.

The results of two of the tests are shown graphically in Figure 1. In A, the pond received N—P—K at the ratio of 1:½:¼ p.p.m. weekly, while in B, the pond received 8:4:2 p.p.m. every four weeks. Much better results from the standpoint of plankton production were secured by the lighter and more frequent application.

The use of light applications to pond waters also appears to be more nearly correct biologically because from a theoretical standpoint it is desirable to add fertilizer in just such amounts as can be converted into animal tissue by fish. The use of small and frequent applications would appear to offer more possibility of accurate control over the process than heavy and less frequent applications. In addition, where there is danger of loss of nutrients from heavy rains, as is the case in the majority of ponds built on small streams, the use of light applications tends to reduce this loss.

Experiments are still in progress to determine how small an application of the mixed fertilizer may be used successfully. At pres-

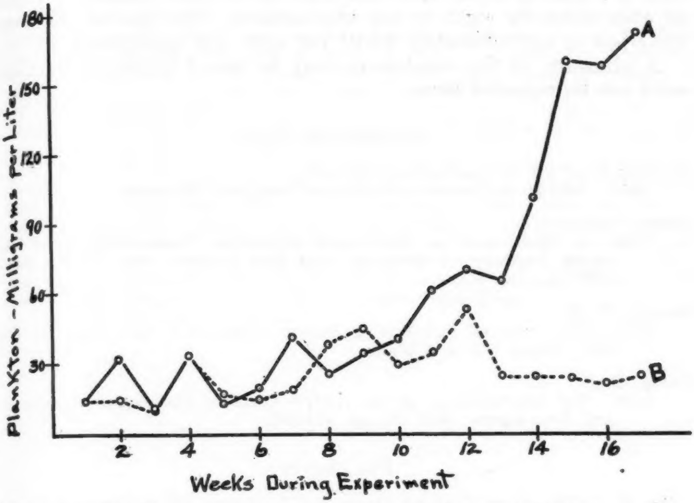


Figure 1.—Plankton production in concrete ponds, March to October, 1937
A—Received weekly applications of 1:½:¼ p.p.m. N—P—K
B—Received an application of 8:4:2 p.p.m. N—P—K every four weeks.

ent, the following amounts are used per acre, based on a ratio of 8:4:2:16 of N—P—K—$CaCO_3$:

40 pounds sulfate of ammonia
60 pounds superphosphate (16 per cent)
5 pounds muriate of potash
30 pounds basic slag (or 15 pounds calcium carbonate)

The above amounts are sufficient to give a 1:½:¼:2 p.p.m. concentration of N—P—K—$CO_3$ in an acre of water 3 feet deep. These materials may be applied separately or the first three may be mixed ahead of time and stored till ready to use. The slag should not be mixed with the other materials until just prior to use as it causes loss of ammonium from the ammonium sulfate. The above amount per acre has been and is being used now in ponds varying in depth from 4 to 18 feet with good results. In deeper ponds, the fertilizer is broadcast in the shallower areas (from 2 to 6 feet in depth) from which it gradually diffuses throughout the rest of the pond. The procedure used at present is to make three applications at weekly intervals in the spring and subsequent applications only as needed, which is usually every four weeks thereafter. Fertiliza-

tion is begun in April and continued to October, requiring a total of approximately eight to ten applications. The cost of the above materials is approximately $1.40 per acre per application.

A summary of the conclusions may be found in the abstract and need not be repeated here.

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## Discussion

Mr. E. L. Wickliff: I would like to ask, how long are the year-old breeder bluegills?

Mr. Swingle: We have never bothered to take measurements of length. We get all of our data from weight. We have found that if we put 200 in one pond and 100 in the other we will have about the same weight of fish, but the one group of fish will be half the size of the other. Where you stock with large numbers you obtain small fish that nobody bothers with, but where you stock with smaller numbers you have fish large enough to catch.

Mr. E. V. Smith: In ponds the pond ecology must be considered as well as plankton production and fish production. I told you in presenting the other paper that the original treatment in the one pond killed the fish, and we had to restock it later in the season and with a smaller number of fish, since we were short on fish for stocking purposes at that time. Therefore that pond had only half as many fish and was stocked later in the season than the other ponds. Perhaps the data for that pond should not have been included.

A large pond, about an acre in area, was stocked this year with bream at the beginning of their second summer. In six weeks they increased their weight twelve-fold, and in another four weeks they doubled in weight again, but in another four weeks the increase was less.

At the same time a smaller fish production was obtained in the ponds with the lower plankton production, and, in general, as the plankton production increased the fish production increased, regardless of whether the fish were in their first summer or their second summer.

Mr. Lloyd Meehean: I have been particularly interested in the fertilization of ponds for the culture of largemouth bass. Most of the experimental work was carried on in Louisiana, and one year in Alabama, and in those ponds I attempted to correlate the various ecological factors, such as plankton, etc., with the production of fish in the pond. In those ponds I found that there was no correlation between plankton or any of the ecological factors, in so far

as I could see, and fish production, except with the total weight of bottom fauna in the pond. The project was an attempt to work out the ecology of the pond, using only fertilizer, and to carry it further by tying in these other types of fishes, such as the bluegill and various other fishes that might increase production in a pond. Mr. Swingle's and Mr. Smith's results on bluegill are very different from those we found on the largemouth bass, and when we attempt to raise the two together in a pond the information in this paper will help in working out this problem.

We also found that up to a certain point the fish production was correlated directly with the bottom fauna, and then there were two points between which there was no correlation, that is, the production in total weight of fish was about the same. Above that point the bottom fauna had no effect at all. At the same time the ponds produced about a given maximum weight of fish, somewhere in the neighborhood of 110 or 120 pounds to the acre, and no matter what the size of the fish was, we got about the same results. We got larger numbers with smaller fish, or smaller numbers with larger fish, but the total weight was approximately the same.

# OBSERVATIONS ON ULCER DISEASE OF TROUT

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ABSTRACT

The various symptoms and effects of ulcer disease are described and discussed. Data on the relative susceptibility of various species and age groups of trout are presented, as well as data concerning the methods of infection, rate of progress, and incubation period of the disease. Experimental evidence is given on the problem of healthy appearing fish which act as carriers of the disease. The effect of a number of drug treatments has been studied. An experiment was performed to determine the effect of diet and vitamins on the resistance of trout to the disease.

INTRODUCTION

During the summer of 1899 Calkins (1899) studied a disease of brook trout in a private hatchery on Long Island. His illustrations and descriptions were so clear and so accurate that there can be no doubt that he dealt with a disease which was identical with that now known as "ulcer disease."

A few years later Marsh (1905) investigated an epidemic, likewise among brook trout, in the New York state fish hatchery at Cold Spring Harbor, located only 9 miles from the hatchery in which the outbreak studied by Calkins occurred. Marsh concluded that the disease investigated by him was identical with that described by Calkins. Fish (1935) stated that in 1918 Marsh reported the same disease from wild fish in Ulster County, New York, many miles up the Hudson River from Long Island.

Moore (1924) was the next one to mention the disease, and she pointed out its similarity to furunculosis. She reported that the sanitary measures adopted at the Cold Spring Harbor hatchery had been singularly successful in preventing a repetition of the 1904 epidemic.

From 1904 until 1933 no serious study of ulcer disease was made, and the work of Calkins and Marsh was largely forgotten. It was not until Fish (1935) undertook his investigation that ulcer disease was again recognized as separate and distinct from furunculosis.

Both Calkins and Marsh gave very good descriptions of the disease, from which one would have no trouble identifying it today. Both of these descriptions are unavailable to most present-day students. Fish likewise gave a very good account, which included one of the most characteristic symptoms of the disease—one overlooked by both of the earlier investigators—namely, the "epithelial tufts."

Since it is quite probable that the disease will present a somewhat variable picture according to its virulence, water conditions, temperature, etc., it seems worth while to describe the malady as it has

occurred under my own observation. This description agrees in the main with that of Fish, but several deviations have been noted with sufficient frequency to warrant mention. The account which follows is based upon an examination of hundreds of fish, many of which have been dissected and examined internally.

## Pathology

The first recognizable symptoms of ulcer disease are positive and clear-cut. These symptoms are the raised, somewhat tufted, white spots, consisting of fine shreds of the superficial skin layers, which Fish (1935) named "epithelial tufts." These tufts may appear on any part of the body, even on the fins, but in most cases the first ones are found on the body proper. They begin as a small point, but spread and deepen rapidly. They are most often first noticed when about a millimeter in diameter, and may be as much as 3 or 4 millimeters across before the corium of the skin is penetrated and a recognizable ulcer is formed. A casual inspection might lead to the conclusion that these tufts are small patches of fungus, but fungus has never been associated with them in our fish.

In a considerable number of cases, but by no means the majority, there is an excessive secretion of slime in the earlier stages of the disease. Sometimes the slime is on a particular region, and sometimes on the entire body of the fish. This slime sloughs off in long, milky patches, and can easily be mistaken for fungus by the casual observer.

Usually the deeper layers of the skin succumb to the invading organism while the tuft is still present as such, and eventually an open sore is formed which increases continuously in diameter and depth. Often the exposed muscle tissue appears firm and healthy, and this has been described as a distinguishing feature between ulcer disease and furunculosis. Such a difference is, however, by no means constant. In the fish that I have examined the ulcers were usually pink to red, the color being often due not merely to exuded blood, but to an inflammation which extended for some distance around the ulcer. In some cases a rather shallow ulcer on the abdomen or lower part of the sides was underlaid with an inflamed region which extended through the body wall to the peritoneum. In such specimens adhesions were sometimes present between the viscera and the inflamed area of the body wall. Occasionally ulcers penetrated the body wall so that a hole was produced and the viscera partly exposed. As the sores enlarge a number may run together producing a single large ulcer with a very irregular outline. For the most part the outlines were circular.

In some of the experiments performed with ulcered fish I have been much disturbed by the presence of an occasional lesion which appeared to be almost identical in appearance with that found in furunculosis. Thus in the experiment described in Section 18, page

148, a total of 109 fish died. Notes were made of the appearance of each fish at the time of death. Of the 109 fish only the first showed no symptoms whatever of ulcer disease. Only 2 died with epithelial tufts as the sole symptoms, while 104 exhibited typical ulcers. Neither of the remaining two specimens had open ulcers, but, instead, each had a swelling on the body which, when cut open, revealed a mass of highly inflamed tissue, bloody in the center, and in general aspect like a typical furunculosis lesion before the latter breaks open. One of these fish had no other symptoms, while the other had pieces out of the caudal fin—a condition quite typical of ulcer disease. Of the 104 fish which died with typical ulcers 6 had, in addition, these same furunculosis-like swellings. Such swellings have also been noted on fish at the Cortland hatchery, from which I obtained all of my original infected stock.

The question of whether furunculosis was present in our fish, along with ulcer disease, could have been settled by bacteriological cultures, but we were not equipped for such work, and so had to depend on general observations. These observations indicated that furunculosis was not present, and that the lesions were merely one of the more unusual manifestations of ulcer disease. The following facts are presented in support of this view:

There were 300 fish included in the experiment referred to in the two preceding paragraphs. The 109 which died have been described. All the survivors were examined individually before being discarded, and not one of these showed any external symptom of furunculosis. On the other hand, all but one had typical ulcer disease lesions, and the one exception had no lesions whatever. I am inclined to think that if furunculosis had been present it would have made more progress. Furthermore, some of the internal symptoms of this disease should have been seen, such as infected kidneys, or little inflamed foci of infection in the muscle tissue. Although forty-eight fish were autopsied at the close of the experiment, not one showed any such conditions. It therefore seems to me that an occasional swollen furuncle is normal in ulcer disease.

A characteristic of the disease is that the edges of the jaws and roof of the mouth of trout are very often attacked (Figure 1). All the soft tissues over a large area of the roof of the mouth may be eaten away. The ulcers at the edges of the jaws often progress very rapidly, especially on the lower jaw where the bones are eaten through and the jaw destroyed.

Small ulcers frequently develop in the fins. These attack the fin rays as well as the soft tissue. Often a group of rays is punctured midway, or even closer, to the base of the fin. These rays then tear out leaving a large irregular notch, and the fin presents the appearance of having had pieces torn out with some instrument (Figure 2). This extremely notched and ragged appearance is most often found in the caudal fin, but the dorsal and pectoral fins are also

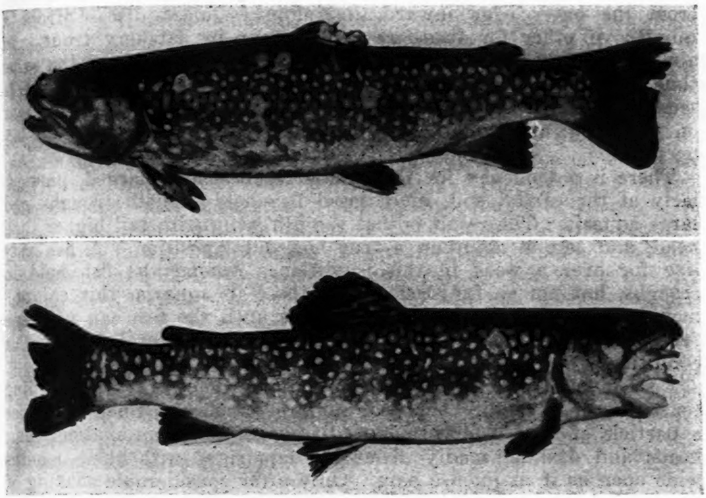

Figure 1.—Yearling brook trout exhibiting some of the typical lesions of ulcer disease. Note the exophthalmia and numerous ulcers on upper specimen. The extent of disintegration of the dorsal fin in this fish is unusual. In the lower specimen the lower jaw has been almost completely eaten away so that the tongue is exposed. Disintegration of jaws is common. The caudal and pectoral fins of both fish are typical of ulcer disease. Both fish were alive up to the time they were photographed.

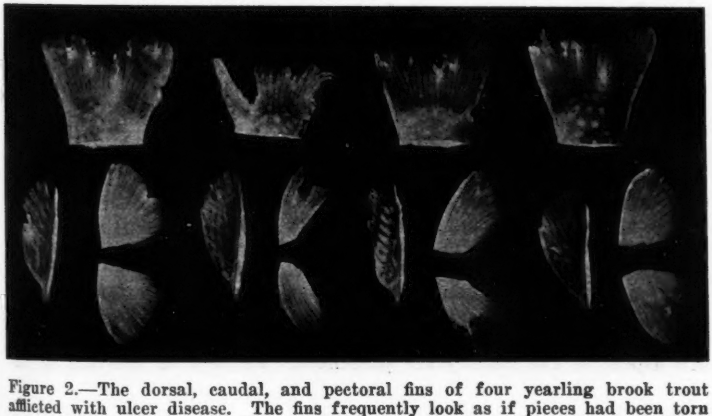

Figure 2.—The dorsal, caudal, and pectoral fins of four yearling brook trout afflicted with ulcer disease. The fins frequently look as if pieces had been torn out with an instrument. The caudal fin is most frequently affected. More severe cases of fin disintegration are common.

attacked. Deep notches, rather than a fairly even erosion of the fins from the outer edge inward, distinguishes ulcer disease from a number of other fin disorders which occur in hatchery trout. In almost all cases the fins disintegrate in this manner about the same time that ulcers develop on the body, but on rare occasions a fish is seen with fins in almost perfect condition whereas ulcers are present on the body; and sometimes a fish with a very bad caudal fin has no ulcers.

There is a tendency for the bladder to become enlarged, particularly at the caudal end, in diseased fish held in both troughs and large aquaria. The result is that the fish swim with tail higher than head, and cannot maintain a true horizontal position. A fish may live for over a week in this condition. Among the fish held in troughs, but not so far seen among those in aquaria, this enlargement of the air bladder often continues until the fish can not even remain right side up. A specimen may live for several days in this condition.

Fish in an early ulcered stage sometimes show peculiar feeding reactions, most readily observed in large aquaria. Such fish seize a particle of food, and then immediately let go again shaking their heads and dashing madly about the aquarium with their mouths wide open as if in intense pain. Only after considerable shaking of the head do they succeed in closing their mouths. A fish which has had this experience may not attempt to feed again for several days. The only explanation I can offer for such behavior is that the disease has attacked the jaw on the inside and interfered with its normal functioning. This seems logical in view of the tendency of the ulcers to attack bone and cartilage. None of these fish showed external jaw ulcers, but none was subjected to careful individual examination to determine the presence of sores on the inside.

As the disease advances the fish lose all appetite. The most badly ulcered specimens refuse all food, even living shrimp, insects, and worms. They may still live for several weeks after reaching this stage.

Some degree of exophthalmia was noticed in a number of diseased individuals. In some fish only one, in others both eyes, protruded markedly.

Fish (loc. cit.) stated that fungus is never found associated with ulcers, and pointed out that this is one difference between this malady and furunculosis. This statement seems true for the vast majority of cases, but not for all. Not once did fungus develop on ulcered fish at the Rome hatchery, but several ulcered fish were obtained at various times from other hatcheries which had considerable fungus.

One additional symptom of ulcer disease may be mentioned, namely, the increased rate of respiration. This symptom was noted by Marsh (1905). Later in this paper some figures which illustrate this aspect of the malady are presented. In view of the lack of in-

formation concerning the effect of other diseases on the respiration rate of trout it is doubtful whether hurried breathing can be of much assistance in diagnosing ulcer disease.

With regard to internal symptoms, it can be stated definitely that there are none. It is true that the air bladder is sometimes enlarged, and that a few adhesions have been seen between various internal organs and the body wall, but in the vast majority of the fish dissected no internal symptoms whatever could be observed. The kidney, liver, and spleen were normal in appearance. In specimens almost dead from the disease (gasping, but unable to maintain balance) one often finds an inflamed large intestine, both intestines filled with a thin yellow slime or numerous gas bubbles. But these conditions are likely to be encountered in any fish which has been dying slowly from whatever cause, and are not specific for ulcer disease.

The statements made in the above paragraph hold true only for macroscopical examination. While microscopical studies of various organs have been made, these studies have not yielded a complete picture of conditions. An identification of the causative organism presents great difficulties, and must await the continuation of the microscopical investigations.

## Experimental Observations

Numerous experiments have been performed in transmitting the disease and in attempting to check it. These experiments will be summarized. The temperature of the water in all this work was 52° F. Clear spring water was used, piped directly from the source. Each trough in which fish were held had its own individual water supply, except where the effluent from one trough was purposely used to infect fish in a trough below.

*1. Transmission of Disease by Contact*. Sixteen healthy yearling brook trout were placed in a large aquarium with several ulcered specimens on March 27. On May 12 the first small ulcer was seen on an experimental fish. By May 22 several of these fish had ulcers, and most of them had epithelial tufts. By June 1 all had ulcers. By June 22 several fish had died, and the experiment was terminated.

Summary: The first ulcers appeared within forty-six days of the beginning of the experiment. Most of the fish were ulcered within fifty-six days. The first deaths occurred within seventy days.

*2. Infection of Yearlings Through Open Wound*. On April 14 ten healthy brook trout yearlings were each slit on the side, above the lateral line, and then placed in a large aquarium with four ulcered fish. On May 12 several of the cuts had almost healed, but the rest had pulled wide open and were inflamed. Some of the fish had epithelial tufts, and most of them had eroded areas on the fins, chiefly the caudal. On May 17 one of the cut fish died; the cut in this fish had developed into an ulcer. On May 22 almost every cut,

including those which had at first showed a tendency to heal, had developed into an ulcer. Caudal fins had large sections missing. On May 31 the experiment was terminated. Although only one fish had died, all had ulcer disease. In only one case had the cut failed to become the site of an ulcer.

Summary: The first ulcers appeared in less than twenty-eight days, and on the site of the cuts. The first fish died within thirty-three days.

*3. Transmission of Disease Through Food.* On April 9 fifteen healthy brook trout yearlings were fed on ground tissue from ulcered trout. A similar feeding was administered on April 22. All other feedings were with uncontaminated food. On May 12 a few fish showed epithelial tufts, and several had eroded areas on the caudal fins. One fish died that day, but without any symptoms of the disease. On May 22 six of the fish had epithelial tufts, and eight were still without blemishes. On June 4 the first ulcers were seen. By June 9 all the fish except one had ulcers or tufts, and the experiment was terminated.

Summary: The first epithelial tufts appeared within thirty-three days of the first infection. The first death, but without symptoms of the disease, occurred within the same period. The first ulcers developed within fifty-six days.

It is perhaps advisable to point out that in this experiment on the transmission of ulcer disease through food the possibility of external contact with the causative agent has not been eliminated.

*4. Relative Susceptibility of Brook, Brown, and Rainbow Yearlings to Ulcer Disease by Contact.* On June 4 six brook, six brown, and six rainbow trout, all healthy yearlings, were placed in a large aquarium with several ulcered brook trout. On June 23 one brook trout showed epithelial tufts, but the other two species were still normal. On June 28 several brook trout showed tufts and small ulcers, whereas the other species were still without symptoms. On July 13 one brook trout died with ulcers, and the rest were all diseased. The brown and rainbow trout were still normal. On July 16 a second brook trout died, and the last of the remaining four died on August 14. At that time all the brown and rainbow trout were still without symptoms, and the experiment was terminated.

Summary: A subjection to ulcer diseases by contact for seventy-one days did not infect brown and rainbow trout yearlings. In the brook trout the first epithelial tufts appeared within nineteen days, the first ulcers within twenty-one days, and the first death occurred within thirty-nine days. The last death occurred within seventy-one days.

*5. Relative Susceptibility of Brook, Brown, and Rainbow Trout Yearlings to Ulcer Disease by Feeding.* On June 22 six brook, six brown, and six rainbow trout, all healthy fish, were placed in a large aquarium and fed daily on the regular hatchery ration until June 26.

Since they were accustomed to their environment and feeding well by that time, the trout were fed tissue from ulcered fish on that date. The brook trout ate the most, and the brown trout the least of the contaminated food. These feedings were repeated on June 30 and July 8. At all other times the hatchery ration was fed.

On July 13 two brook trout exhibited epithelial tufts. On July 23 several fish of the same species had small ulcers and the brown and rainbow trout had suspicious looking swellings, unlike tufts, on the body. On August 6 one brook trout died. By August 20 the last of the brook trout died. At that time all the rainbow trout were still without symptoms of the disease, but one brown trout had two small ulcers, and several more had sores on the tip of the upper jaw. On this date the experiment was terminated.

Summary: The brown trout proved susceptible to infection by feeding, but much less so than the brook. The rainbow trout were immune for the period of the experiment. First signs of tufts in the brook trout appeared within seventeen days, the first ulcers within twenty-seven days, and the first death within forty-one days. The last brook trout died within fifty-six days of the first contaminated feeding. In this experiment, as in No. 3, the possibility of infection by contact was not eliminated.

6. *Progress of the Disease in Fingerling Brook Trout Infected by Contact.* On September 2 fifty fingerling brook trout were placed in a trough that received the effluent from another trough containing several diseased yearlings. On September 20 the fingerlings showed tufts on the caudal fin only, and this fin had pieces missing. On September 28 there were many epithelial tufts on the caudal fins, and a few on the body; there were also open sores on the tip of the upper jaw. The fish were discarded on this day.

Summary: The first epithelial tufts appeared on the caudal fins in eighteen days. The first body tufts, and the first sores appeared in twenty-six days.

7. *Relative Susceptibility of Brook, Brown, and Rainbow Fingerlings to Ulcer Disease by Six-Day Contact.* On July 17 fifty fingerlings of each of the three species of trout were placed in troughs receiving the effluent from troughs that contained ulcered yearlings. On July 23 the fingerlings were removed to uncontaminated individual troughs. On August 20 the first ulcers were seen on the brook trout. On August 21 an ulcered brook trout died. On August 23 observations were terminated. On this date most of the brook trout showed the disease, several of the brown trout were ulcered and all the rainbow trout appeared perfectly healthy.

Summary: The first ulcers appeared on the brook trout within thirty-four days of the beginning of the infection. The first brook trout died within thirty-five days. The first ulcers were seen on brown trout within thirty-seven days. Rainbow trout were not susceptible.

The results of this experiment agree very well with the situation witnessed by me during September 1937 at the Caledonia hatchery. At that place a feeding experiment was being run with fingerling brook, brown, rainbow, and lake trout. Ulcer disease was rampant at the time of my visit. It was very bad among the brook trout, bad among the lake and brown trout, and not present at all among the rainbow trout. The lake trout had more ulcers than the brown.

8. ***Relative Susceptibility of Brook, Brown, and Rainbow Fingerlings to Ulcer Disease by 24-Hour Contact.*** On July 8 thirty fingerlings of each of the three species of trout were placed in a trough into which the water flowed from a trough that contained ulcered yearlings. After twenty-four hours the fingerlings were transferred to uncontaminated troughs. On August 20 several of the brook trout showed ulcers. On August 23 the first brook trout died and the observations were terminated. All the brown and rainbow trout were still normal in appearance at that time.

Summary: Twenty-four hours of exposure to ulcer disease by contact were sufficient to infect brook trout fingerlings, but brown and rainbow trout showed no signs of the disease during the forty-six days of observation.

9. ***Susceptibility of Brook Trout Fingerlings to Ulcer Disease by 24-Hour Contact.*** In a repetition of the above experiment with brook trout alone they developed ulcers within twenty-six days, and the first fish died on the twenty-seventh day.

10. ***Susceptibility of Brook Trout Fingerlings to Ulcer Disease by Twelve-Hour Contact.*** On August 26 fifty brook trout fingerlings were placed for twelve hours in a trough contaminated by the effluent from a trough of diseased yearlings. The fingerlings were then transferred to uncontaminated water. On September 28 many of the fish showed tufts, and the experiment was terminated.

Summary: A twelve-hour exposure to ulcer disease was sufficient to infect fingerling brook trout. The first epithelial tufts appeared within thirty-three days.

11. ***Brown Trout Yearlings as Carriers of Ulcer Disease.*** In this experiment six brown trout which had been exposed to ulcer disease were used. Three had been fed ulcered brook trout tissue three times, and had been held with diseased brook trout from June 26 to August 21. The other three had been held with ulcered brook trout from June 2 to August 14, but had not been fed diseased tissue. From August 23 to 25 these six brown trout were held in an uncontaminated trough with a good flow of water, being given a 20-minute bath in 3 per cent salt solution just previous to being placed in the trough. It was hoped that this treatment might remove infective organisms from the surface of the fish. On August 25 the fish were placed with healthy brook trout in an aquarium which had been sterilized with chlorinated lime.

On September 9 several brook trout showed tufts. On September

18 several showed small ulcers, and one ulcered specimen died. On September 23 a second ulcered brook trout died. On September 28 the experiment was terminated. At that time all the remaining brook trout were badly ulcered, and all the brown trout were still without the faintest symptoms of the disease.

Summary: Brown trout are able to act as carriers of ulcer disease for at least a short period of time. The first tufts appeared on the brook trout within fifteen days. The first brook trout died within twenty-four days.

*12. Rainbow Yearlings as Carriers of Ulcer Disease.* Nine rainbow yearlings which had been in contact with ulcered brook trout from June 2 to August 14 without acquiring the disease were used in this experiment. On August 20 the fish were given a 20-minute bath in 3 per cent salt solution, and then placed in a clean trough. On August 21 they were placed in a sterilized aquarium and held there till August 24, when five healthy brook trout yearlings were added.

On September 16 one of the brook trout showed tufts. On September 18 the fish began to lose appetite. On September 28 three of them had numerous ulcers. On this day observations were discontinued. All the rainbow trout still appeared perfectly healthy.

Summary: Rainbow trout, like brown, are able to act as carriers of ulcer disease for at least a short period of time. The first tufts appeared on the brook trout twenty-three days, and the first ulcers thirty-one days after the beginning of the experiment.

*13. Observations on the Rate of Respiration of Infected Fish.* On March 27 a number of healthy brook trout yearlings were placed in an aquarium with ulcered 2-year-old and adult brook trout. The rate of respiration of these fish was determined with the aid of a stop watch at various times as indicated in Table 1.

**TABLE 1. RESPIRATION RATE OF ULCERED ADULT BROOK TROUT, AND OF YEARLING BROOK TROUT AT SEVERAL STAGES OF INFECTION**

| Date | Group | Number of fish employed | Number of respirations | | Comments |
|---|---|---|---|---|---|
| | | | Average per minute | Range | |
| April 6 | Yearling | 11 | 46.6 | 37-69 | No disease signs |
| April 6 | Ulcered | 12 | 74.7 | 49-101 | All had ulcers |
| May 12 | Yearling | 12 | [1]59.0 | 46-74 | Tufts & small ulcers present |
| May 12 | Ulcered | 4 | 66.8 | 53-74 | Eight dead since previous count |
| June 21 | Yearling | 10 | 79.3 | 70-98 | All diseased |
| June 21 | Ulcered | 3 | 85.0 | 65-100 | One dead since previous count |

[1]On this date the respiration rate of fish from the same lot, but not infected, was 45 per minute.

Summary: Inspection of Table 1 reveals an increase in the rate of respiration of the yearling fish from an average of 46.6 respirations per minute before they showed symptoms of disease to an

average of 79.3 respirations per minute after reaching an advanced stage of the malady.

*14. **Effect of Chemical Baths on Ulcer Disease.*** Because of the superficial nature of the sores in ulcer disease, as compared with furunculosis, there has been a tendency on the part of fish culturists and investigators (Fish 1935, Davis 1937) to recommend chemical baths as a means of controlling the disease. I have performed numerous experiments along this line, none of which gave encouraging results. Since the experiments were all negative they will not be described in detail. Only enough of the procedure will be given to indicate the lines along which the work was done.

(*a*) ***Salt Baths.*** A great many baths in 3 per cent salt solution were given to ulcered fish. These baths lasted from seven to twenty minutes, and were given daily in many cases. No beneficial effects whatever were noted.

(*b*) ***Lugol's Solution*** (*1 gram iodine + 2 grams potassium iodide + 100 cubic centimeters water*). Lugol's solution was poured directly on ulcers. Baths were given in 1:35,000 up to 1:25,000 parts of the solution. Small quantities of the solution were added daily to food, and to aquarium water containing diseased fish. No beneficial effects were observed.

(*c*) ***Copper Sulphate and Potassium Permanganate.*** The question arises whether disinfecting baths might not prevent the disease if started before external symptoms appeared.

On July 23 three lots of fingerling brook trout, fifty-two in each lot, were placed in troughs receiving the effluent from troughs containing ulcered yearlings. The fingerlings were kept in this water, and therefore subjected to infection throughout the experiment.

On July 26 the first baths were given. The three groups were treated as follows:

Lot 1. No treatment.

Lot 2. Three minutes in 1:10,000 $KMnO_4$. After three treatments the time was reduced to two minutes.

Lot 3. Two minutes in 1:2,000 $CuSo_4$, with just sufficient HCl added to hold the copper salt in solution.

Treatments were given on July 26, 29, August 2, 9, 12, and 16. Thus they were started long before any ulcer symptoms appeared.

In both of the treated groups a few fish died before showing signs of disease. The numbers that died follow: Lot 1 (control) 0; Lot 2 ($KMnO_4$) 4; Lot 3 ($CuSO_4$) 2.

On August 13 the first ulcered fish died, one of those treated with $CuSO_4$. After this date every fish which died had ulcers, and the mortality record for this period was as follows: Lot 1 (control) 8; Lot 2 ($KMnO_4$) 19; Lot 3 ($CuSO_4$) 23.

On August 25 the experiment was terminated. All the surviving fish in all groups were badly diseased. All three groups were sub-

sequently mixed together and held till September 28, by which date only two fish still survived.

This experiment is subject to so many variations that one needs to be cautious in drawing conclusions as to the effectiveness of chemical dips. As here used they were not at all effective, even though started long before symptoms of the disease appeared. In my opinion it is doubtful whether any of our commonly used chemical baths can effect a cure for ulcer disease or act as preventatives.

*15. Effect of Certain Drugs Administered Orally.*

(*a*) *Sulfanilamide.* This drug has been tried by a number of investigators. Tunison and McCay (1937) indicated some hopeful signs from its use, but no real cures. The compound was administered by me in gelatin capsules placed directly in the stomach of the fish, and also mixed with the food. It was given in a wide range of quantities, up to amounts which killed the fish. No beneficial effects were observed from any method of administration, or from any quantity of the drug.

(*b*) *Stannoxyl.* This is a tin compound which has been used for boils in man, and various claims have been made for it. It was fed to ulcered yearlings in various amounts over a three-week period. No beneficial effects were noted.

(*c*) *Quinine Hydrochloride and Quinine Sulphate.* Various amounts of these drugs were administered to ulcered fish. The compounds were introduced directly into the stomach of the fish in gelatine capsules, and also mixed with the food. The trout showed a great tolerance of these substances, and large doses could be administered. No benefits resulted from their use.

*16. Recovery of Brook Trout from Ulcer Disease.* Of fifteen ulcered brook trout obtained from the Cortland hatchery in March, 1937, two 2-year-olds recovered completely, as far as external symptoms were concerned. These fish had to be discarded on September 24 because of the necessary shutting off of the water supply to the laboratory, and, therefore, were unfortunately not tested for their disease-carrying capacity.

At no time was there, among the many hundreds of fish experimented with at the Rome hatchery, any indication of recovery in fingerlings or yearlings. Not all experimental fish died, for most of the experiments were discontinued upon the appearance of the disease. Space did not permit keeping all the fish until they expired. No indications of recovery, however, have been noted in brook trout of the size and strain employed in this study. This observation is quite in accord with the experience of the earlier investigators of the disease. Calkins (1899) reported that the epidemic he witnessed "did not abate until every fish had died." Marsh (1905) did not mention any fingerlings in the epidemic he studied, but said that it "continued until all the yearlings, and most of the adult stock had died, a total of some 12,000 fish."

In the three New York state hatcheries where the disease is found its effect is similar. These three are the Saranac Inn, the Caledonia, and the Randolph hatchery. The disease is also found in the Cortland hatchery, but the experimental nature of the work done there prevents forming a true picture of the disease under normal hatchery conditions. In the three state hatcheries mentioned above the disease has probably been present for years, though it was formerly confused with furunculosis.

In general, symptoms of the disease have appeared toward the end of July, or somewhat later, and tended to disappear as cold weather set in. Ulcers have begun to show on the fingerling trout, and mortality to rise sharply, during August. This situation has usually been met by a hurried planting of fingerlings, so that all ponds have been much thinned down by the end of September. This thinning, together with the cooler water temperatures of October and, perhaps, the ageing of the fish, has generally accomplished a lowering of the mortality rate. During the winter months only an occasional ulcered fish can be seen among the yearlings and the adult brood stock, and the losses are small. The disease has undoubtedly been carried over in the older fish, however, and toward the end of the following summer breaks out again in the new crop of fingerlings.

Experience at the Caledonia hatchery indicates that one attack of the disease does not render the fish immune to subsequent attacks. The fingerlings which survive one epidemic may again exhibit ulcers, and a rising mortality rate, the following year. But losses are seldom high among the yearlings and adults.

One fact which stands out is that in none of the hatcheries has there been anything approaching the complete annihilation of brook trout reported by the earlier investigators. Perhaps a partial immunity has been built up, or perhaps our present strain of the disease is less virulent than that described at the turn of the century.

My own experiments at Rome, New York, indicate that the disease has lost none of its virulence as far as fingerlings and yearlings are concerned. The stock of fish I used came from an uninfected source and is perhaps less resistant than the fish in the three abovementioned state hatcheries. This question remains to be investigated.

*17. Immunity of Small Brook Trout Fingerlings to Ulcer Disease.* I have been unable to infect brook trout fingerlings with ulcer disease up to the end of May. The fingerlings experimented with were from very late eggs, and so were rather small for this time of year. At the end of May they averaged around 1¾ inches in length. Indications are that young fingerlings are immune, though at what period they become susceptible has not yet been determined.

*18. Effect of Various Diets and Vitamins on Resistance to Ulcer Disease in Yearling Brook Trout.* Six lots of yearling brook trout were used in this experiment, fifty fish in each lot. The diets which

were tested for their effect on the resistance of the fish to ulcer disease are given below.

Diet I. 50 per cent fresh meat, consisting of equal parts of pork "melts" (spleen) and fish. 50 per cent dry meals, consisting of equal parts of cottonseed meal, skimmilk, and fish meal.

Diet II. Same as Diet I, but with the addition of vitamins A, B, C, D, and G, in the form of cod liver oil, yeast, and orange juice.

Diet III. 75 per cent fresh meat, as described in Diet I. 25 per cent meals, as listed in Diet I.

Diet IV. Same as Diet III, but with the addition of the vitamins named in Diet II.

Diet V. 75 per cent fresh meat, consisting of equal parts of pork "melts," fish, and beef liver. 25 per cent dry meals, as listed in Diet I.

Diet VI. Same as Diet V, but with the addition of the vitamins named in Diet II.

The food was made up fresh every two days, and to the amount that the fish would consume in the two-day period the vitamin ingredients were added in the following quantities: 1 tablespoonful of cod liver oil, 20 cubic centimeters of orange juice, and ½ cake of Fleischmann's yeast. This was the maximum amount of the vitamin substances which could be added without making the feed mixture too soft for the fish. It is estimated that the trout consumed only about two-thirds of the food, and therefore only two-thirds of the units of vitamins contained in the above ingredients.

The fish were weighed every two weeks, and it was found that the growth was about the same in all six lots for the first sixty days of the experiment. After that the varying amount of disease in the different lots affected the growth.

The fish were started on their diets on December 20, but were not exposed to ulcer disease until January 17. Thus they were given a four-week conditioning period during which the diets had a chance to affect the vigor of the fish before any infection was introduced.

On January 17, 18, and 19, the diets were suspended, and on each of these days all six lots were fed an identical infected mixture in order to start the disease. This mixture consisted of three badly ulcered fish ground up and thoroughly mixed with enough other meat to provide an adequate feeding for all six groups. Thus nine ulcered trout were consumed over a three-day period. Thereafter, all six lots were returned to their experimental diets, and these diets were continued without interruption until the end of the experiment.

Complete mortality records for the entire experiment are shown in graphical form in Figure 3. These curves show the number of fish alive in each group from the time the first fish died until the experiment was terminated. It may be seen that the mortality was most severe in groups I and IV. The other four groups did somewhat better, all four having about the same mortality.

The curves indicate that none of the six diets gave the fish im-

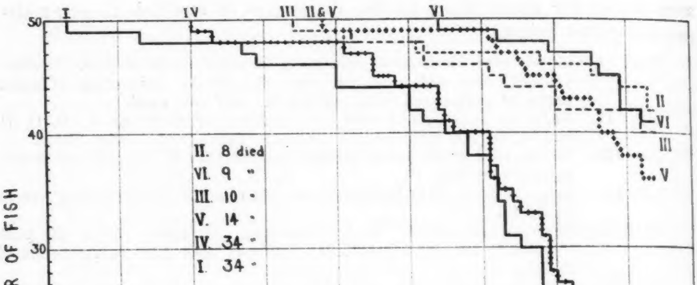


**Figure 3.—Mortality from ulcer disease of six lots of brook trout fed different diets. Composition of diets given in Experiment 18.**

munity to ulcer disease. There is every reason to believe that all of the fish in each lot would have died if the experiment had been continued long enough. The fish in lots II, III, V, and VI started dying later, and succumbed at a slower rate than those in lots I and IV. If this difference was due to the effect of the diet, rather than mere chance, it may be concluded that Diets II, III, V, and VI were superior to Diets I and IV.

If we disregard the element of chance, any difference in disease resistance between groups I and II must have been due to the addition of vitamins in one diet. It should be remembered that these two diets were low in fresh meat content, and therefore might have been expected to reflect an addition of vitamins more than would Diets III to VI.

Diet VI, with its added vitamins, was no better than Diet V. Diet IV, however, gave so much poorer results than III that it would appear that the addition of vitamins was actually harmful; such conclusion is difficult to accept.

With respect to the effect of vitamins on the disease we may regard the results of this experiment as inconclusive. They suggest that the addition of vitamins to a diet containing 50 per cent fresh meat may be beneficial, but that when the diet contains as much as 75 per cent fresh meat no benefit is to be derived from the added vitamins.

## Summary and Conclusions

1. Ulcer disease is primarily a disease of brook trout. Lake and brown trout are susceptible, whereas rainbow trout are very resistant and perhaps immune.

2. A description of the symptoms of the disease is given.

3. Ulcer disease is extremely deadly for fingerlings and yearlings. Older fish contract the disease and exhibit ulcers, but usually recover. Fingerlings under 2 inches in length are apparently immune.

4. In pure spring water with a temperature of 52° F. the first symptoms of ulcer disease (epithelial tufts) appeared in from two to three weeks (sometimes more) after infection. The first recognizable ulcers appeared from three to five weeks after infection, and the first deaths within about the same period.

5. The causative organism is not yet known. Despite the superficial nature of the lesions there is some reason for thinking that the agent can pervade the body of the fish. Methods of transmission, and the not infrequent death of fish without any external symptoms support this view.

6. Both brown and rainbow trout can act as carriers of the disease, at least for short periods.

7. A number of drugs were administered orally, but had no effect on the disease. These drugs included iodine, Sulfanilamide, Stannoxyl, and quinine.

8. Chemical baths had no effect in checking the disease, or in preventing it. These baths consisted of salt, copper sulphate, potassium permanganate, and Lugol's solution (iodine).

9. Addition of vitamins in the form of cod liver oil, orange juice, and yeast to the diet gave conflicting results in preventing ulcer disease, and offered little hope that such addition will prove of much advantage where a diet of fresh meat and fish is used.

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# THE AGE, GROWTH, AND FEEDING HABITS OF THE WHITEFISH, *COREGONUS CLUPEAFORMIS* (MITCHELL), OF LAKE CHAMPLAIN[1]

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## ABSTRACT

This study is based on 120 whitefish collected in northern Lake Champlain (Missisquoi Bay) in 1930 and on 175 whitefish taken in southern Lake Champlain in 1931. Since the whitefish population had not been exploited commercially after 1912 in United States waters and after 1915 in Canadian waters, its study should be of interest in showing the characteristics of a population practically untouched by man. Data have been presented on length frequencies, age composition, growth, coefficient of condition, sex ratio, standard length-total length relationship, and feeding habits. The data indicated that the Missisquoi Bay population was disturbed (probably by the early fall seining of 1930) before our samples were taken so that the original length distributions no longer existed. The southern Lake Champlain material, however, showed a consistency which indicated that the population had not been exploited to any extensive degree, if at all. When the northern population was compared with the southern the former was found to differ from the latter in the following respects, which differences pointed to some disturbance of the northern stock in the lake:

1. By possession of lower modes and smaller grand averages of length.
2. By absence of very old individuals.
3. By absence of a series of equally abundant age groups or, in other words, by the presence of a decided dominance of one or two age groups.
4. By a radical disagreement between the sexes in their age-frequency distribution.
5. By a disagreement between the sexes with respect to maximum lengths attained.

All of the differences between the two collections could, however, not be attributed to exploitation. The following characteristics indicated the presence of two distinct populations in the lake:

1. Presence of a spawning ground at each end of the lake.
2. Differences in calculated lengths and increments of length (growth rates).
3. Differences in the actual lengths and weights of corresponding age groups at capture.
4. Differences in the coefficient of condition and the length-weight relationship.

The discovery of the presence of apparently two separate populations of whitefish in Lake Champlain was wholly unexpected by us.

## INTRODUCTION

The whitefish, *Coregonus clupeaformis* (Mitchell), of Lake Champlain (locally known as "shad") formerly supported a commercial seine fishery during the fall. Because of considerable international controversy over the asserted destructiveness of fall seining to the game fishes, no licenses were granted to commercial fishermen of the

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Province of Quebec after 1915. Vermont discontinued the issuance of commercial seining licenses in 1913.

In 1929 an International Fact-finding Commission composed of Mr. James A. Rodd, representing the Dominion of Canada, and Dr. John Van Oosten, representing the United States, was appointed to investigate international controversies concerning the fisheries of Lake Champlain. As a part of the field investigations special seining licenses were granted to six Quebec fishermen in the fall of 1930 in order that the Commission might secure information on the abundance of whitefish and game species in the Canadian (Missisquoi Bay) waters of Lake Champlain at that time of the year. The scales of 120 whitefish were obtained.

In the fall of 1931, at the request of and with assistance provided by the State of Vermont, the senior author made experimental seine hauls along the Vermont shore between Larrabee's Landing and the Crown Point ferry landing in the southern third of Lake Champlain. During this seining the scales of 180 whitefish (only 175 could be used) and the stomachs of 141 were collected.

Since it is highly improbable that any additional data on the Lake Champlain whitefish will be obtained in the near future, it is believed advisable to summarize the information at hand and make it available in published form.

We wish to express our appreciation to the International Fact-finding Commission for permission to use the whitefish data and materials collected under its jurisdiction in Missisquoi Bay.

## Materials and Methods

The data upon which this study is based were obtained from 120 sexually mature whitefish collected from the Province of Quebec waters of Lake Champlain (Missisquoi Bay) on four dates during the period October 24 to November 4, 1930, and from 175 sexually mature whitefish collected from Lake Champlain in the vicinities of Larrabee's Landing and the Crown Point ferry landing in Vermont on twelve dates during the period October 27 to November 11, 1931. These fish represented supposedly random samples of the spawning population for all specimens captured in a seine haul were studied. None of the fish was spent although some of them were ripe and ready to spawn. Standard length, total length, weight, sex, and stage of sexual maturity were recorded on the scale envelopes in the field.

The whitefish scales were cleaned, mounted in a glycerine-gelatine solution, and studied in the customary manner by means of a microprojection apparatus at a magnification of 25.7 diameters. Calculation of growth from the measurements of scale diameters was made by direct proportion. This method has been applied successfully by the senior author and by others to the whitefish and other coregonid species. The age of each fish, expressed in terms of the

**TABLE 1. LENGTH FREQUENCIES AND LENGTH-WEIGHT RELATIONSHIP OF THE WHITEFISH OF LAKE CHAMPLAIN, ALL AGE GROUPS COMBINED.**

| Standard length (milli-meters) | Equivalent mid-point, total length (inches) | Number of Individuals | | | | | | Average Weight (pounds) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Missisquoi Bay—1930 | | | Southern Lake Champlain—1931 | | | Missisquoi Bay—1930 | | Southern Lake Champlain—1931 | |
| | | Males | Females | Total | Males | Females | Total | Males | Females | Males | Females |
| 300-309 | 14.3 | 1 | .. | 1 | .. | .. | .. | 1.0 | .. | .. | .. |
| 310-319 | 14.8 | 2 | .. | 2 | 1 | .. | 1 | 1.0 | .. | 1.0 | .. |
| 320-329 | 15.2 | .. | .. | .. | 1 | .. | 1 | .. | .. | 1.3 | .. |
| 330-339 | 15.7 | 1 | .. | 1 | 1 | .. | 1 | 1.3 | .. | 1.2 | .. |
| 340-349 | 16.2 | 4 | .. | 4 | 1 | .. | 1 | 1.5 | .. | 1.5 | .. |
| 350-359 | 16.6 | 2 | 1 | 3 | 1 | 1 | 2 | 1.6 | 2.0 | 1.5 | 1.6 |
| 360-369 | 17.1 | 3 | .. | 3 | .. | .. | .. | 1.7 | .. | .. | .. |
| 370-379 | 17.6 | 4 | 1 | 5 | .. | 2 | 2 | 1.8 | 2.0 | .. | 2.2 |
| 380-389 | 18.0 | 3 | .. | 3 | 1 | 1 | 2 | 2.0 | .. | 2.0 | 2.3 |
| 390-399 | 18.5 | 1 | 2 | 3 | 5 | 4 | 9 | 2.3 | 2.5 | 2.4 | 2.4 |
| 400-409 | 19.0 | 5 | 3 | 8 | 3 | 3 | 6 | 2.2 | 2.4 | 2.5 | 2.5 |
| 410-419 | 19.4 | 6 | 4 | 10 | 4 | 4 | 8 | 2.8 | 2.8 | 2.6 | 2.7 |
| 420-429 | 19.9 | 6 | 6 | 12 | 5 | 3 | 8 | 2.9 | 2.8 | 2.9 | 3.3 |
| 430-439 | 20.4 | 5 | 2 | 7 | 11 | 2 | 13 | 2.7 | 2.7 | 3.0 | 3.0 |
| 440-449 | 20.8 | 5 | 9 | 14 | 6 | 6 | 12 | 3.3 | 3.4 | 3.1 | 3.5 |
| 450-459 | 21.3 | 6 | 9 | 15 | 10 | 11 | 21 | 3.3 | 3.5 | 3.6 | 3.8 |
| 460-469 | 21.8 | 1 | 6 | 7 | 4 | 5 | 9 | 3.3 | 3.7 | 3.9 | 4.3 |
| 470-479 | 22.2 | .. | 3 | 3 | 9 | 10 | 19 | .. | 3.7 | 4.1 | 4.1 |
| 480-489 | 22.7 | 3 | 3 | 6 | 11 | 8 | 19 | 4.1 | 4.0 | 4.2 | 4.6 |
| 490-499 | 23.2 | 2 | 3 | 5 | 11 | 5 | 16 | 4.0 | 4.2 | 4.6 | 5.1 |
| 500-509 | 23.5 | .. | 1 | 1 | 5 | 5 | 10 | .. | 4.9 | 4.9 | 5.3 |
| 510-519 | 23.9 | .. | 3 | 3 | 5 | .. | 5 | .. | 5.0 | 5.1 | .. |
| 520-529 | 24.4 | .. | 3 | 3 | .. | 4 | 4 | .. | 5.4 | .. | 5.4 |
| 530-539 | 24.8 | 1 | .. | 1 | .. | 2 | 2 | 5.8 | .. | .. | 5.6 |
| 540-549 | 25.3 | .. | .. | .. | 2 | 1 | 3 | .. | .. | 5.8 | 6.2 |
| 550-559 | 25.8 | .. | .. | .. | 1 | .. | 1 | .. | .. | 5.9 | .. |
| Total | ...... | 61 | 59 | 120 | 98 | 77 | 175 | .. | .. | .. | .. |

number of annuli on the scales, was determined independently by each of the authors. The scales upon which they disagreed were re-examined by both investigators together and almost all differences were adjusted. Ages could not be determined accurately for five, or 1.7 per cent, of the 180 southern Lake Champlain fish examined, and the data of these individuals were discarded.

The stomachs of the 141 whitefish collected in southern Lake Champlain were examined immediately upon removal from the fish. Empty stomachs were discarded and recorded as "empty" on the scale envelopes. Stomachs which contained food were wrapped individually in pieces of muslin, to each of which was attached a numbered metal tag. The wrapped stomachs were preserved in formalin and washed and transferred to 70 per cent alcohol in the laboratory. Laboratory analyses of the stomach contents consisted of identifying each item in the food as accurately as possible and then determining the volume of each item by liquid displacement in a graduated cylinder partly filled with alcohol.

## Length Frequencies, Age Composition, and Sex Ratio

Table 1 presents the standard length frequencies of the combined age groups of each collection according to sex, and the average weight of each length group (length-weight relationship). Although length frequencies were made for each age group, the data for each group were too few to justify the publication of the detailed table. Table 1 shows that the males ranged from 300 to 559 millimeters standard length, and the bulk varied from 400 to 459 millimeters in 1930 (54 per cent) and from 430 to 499 millimeters in 1931 (63 per cent). The females ranged from 350 to 549 millimeters, and the bulk varied from 420 to 469 millimeters in 1930 (54 per cent) and from 440 to 489 millimeters in 1931 (52 per cent). Sixty-one per cent of the 1930

**TABLE 2. NUMERICAL AND PERCENTAGE FREQUENCY DISTRIBUTION OF THE WHITEFISH COLLECTED IN MISSISQUOI BAY IN 1930 AND IN SOUTHERN LAKE CHAMPLAIN IN 1931, ACCORDING TO AGE GROUP AND SEX**

| Age group | Numerical frequency 1930 Males | 1930 Females | 1931 Males | 1931 Females | Percentage frequency 1930 Males | 1930 Females | 1931 Males | 1931 Females |
|---|---|---|---|---|---|---|---|---|
| II | 3 | -- | -- | -- | 4.9 | -- | -- | -- |
| III | 5 | -- | 5 | -- | 8.2 | -- | 5.1 | -- |
| IV | 13 | 3 | 1 | 5 | 21.3 | 5.1 | 1.0 | 6.5 |
| V | 2 | 1 | 11 | 6 | 3.3 | 1.7 | 11.2 | 7.8 |
| VI | 7 | 3 | 3 | 7 | 11.5 | 5.1 | 3.1 | 9.1 |
| VII | 17 | 22 | 9 | 11 | 27.9 | 37.3 | 9.2 | 14.3 |
| VIII | 5 | 12 | 10 | 11 | 8.2 | 20.3 | 10.2 | 14.3 |
| IX | 1 | 3 | 14 | 9 | 1.6 | 5.1 | 14.3 | 11.7 |
| X | 5 | 3 | 13 | 8 | 8.2 | 5.1 | 13.3 | 10.4 |
| XI | 1 | 2 | 11 | 7 | 1.6 | 3.4 | 11.2 | 9.1 |
| XII | 2 | 6 | 12 | 3 | 3.3 | 10.2 | 12.2 | 3.9 |
| XIII | -- | 2 | 4 | 2 | -- | 3.4 | 4.1 | 2.6 |
| XIV | -- | -- | 1 | 2 | -- | -- | 1.0 | 2.6 |
| XV | -- | -- | 1 | 4 | -- | -- | 1.0 | 5.2 |
| XVI | -- | 1 | 1 | 2 | -- | 1.7 | 1.0 | 2.6 |
| XVII | -- | 1 | 2 | -- | -- | 1.7 | 2.0 | -- |

fish (sexes combined) ranged from 400 to 469 millimeters (19.0 to 21.8 inches total length) and 68 per cent of the 1931 specimens varied from 430 to 509 millimeters (20.4 to 23.5 inches total length) in length. In both sexes the modes of length of the southern Lake Champlain individuals were in general higher than those of the Missisquoi Bay fish.

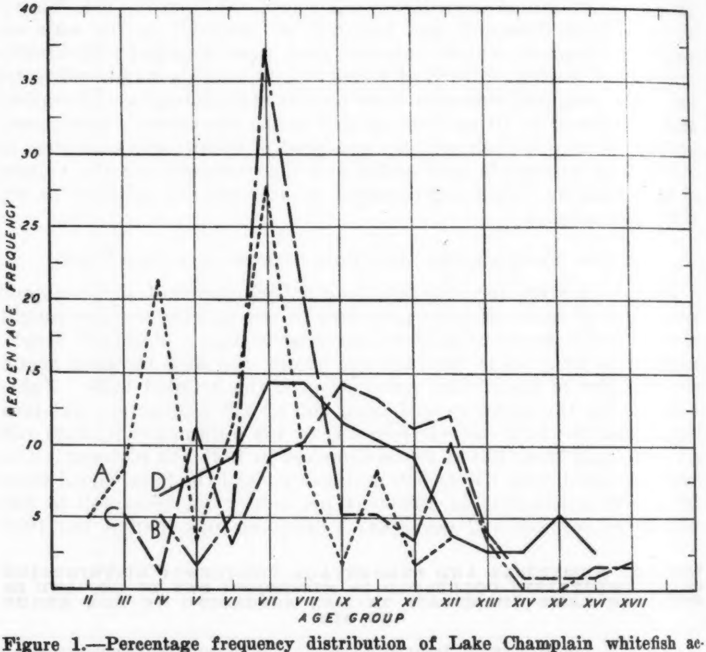


**Figure 1.—Percentage frequency distribution of Lake Champlain whitefish according to age groups. A = Missisquoi Bay males, B = Missisquoi Bay females, C = Southern Lake Champlain males, D = Southern Lake Champlain females.**

Table 2 shows the numerical and percentage frequency distribution of the Lake Champlain whitefish according to age group and sex. Percentage frequency curves are presented in Figure 1. In the 1930 sample the males ranged from 2+ to 12+ years in age, age-groups IV and VII predominating (21.3 and 27.9 per cent), and the females varied from 4+ to 17+ years in age, age-groups VII and VIII predominating (37.3 and 20.3 per cent). In both sexes age-group VII (year-class 1923) ranked first in abundance. In the 1931 collection the males ranged from 3+ to 17+ years in age, age-groups IX and X

showing a tendency to dominate the catch (14.3 and 13.3 per cent), and the females varied from 4+ to 16+ years in age, with a tendency for age-groups VII and VIII to dominate (14.3 and 14.3 per cent). In the 1931 males age-groups V, VII, VIII, IX, X, XI and XII closely approximated one another in abundance, the percentage varying from 9.2 to 14.3, and a similar approximation occurred among age-groups V, VI, VII, VIII, IX, X, and XI of the 1931 females, the percentage ranging from 7.8 to 14.3 (note the striking differences between the 1930 and 1931 curves of Figure 1).

On the basis of Tables 1 and 2 the following general statements may be made.

(1) Since the samples represent spawning schools it may be concluded that the males enter the spawning run at a smaller size than do the females and first reach sexual maturity in their third or fourth year of life, one or two years earlier than do the females, which apparently do not begin to spawn until their fifth year. It is probable, however, that the majority of both sexes reaches maturity later than is indicated here.

(2) The sex ratio (Table 1) was approximately 50-50 in the Missisquoi Bay whitefish in 1930, whereas in southern Lake Champlain in 1931 the males comprised 56 per cent of the sample and the females 44 per cent.

(3) The nearly equal abundance of a series of age groups in both sexes in 1931, or the absence of a decided dominance (which absence is not normal in fish populations), and the attainment of the same maximum lengths by both sexes in 1931, in spite of the fact that the males reached sexual maturity at a smaller size than did the females and normally would be expected to disappear first, are probably, in part at least, the result of the non-exploitation of the species in southern Lake Champlain which permitted the fish to survive to an old age and large size. There is no evidence to suggest that during the years under consideration any one year class dominated the catch to any significant degree.

(4) The lower length-frequency modes, the paucity of very old individuals, and the striking disagreement between the sexes in their age-frequency distributions in the 1930 sample as compared with the 1931 specimens suggest that the Missisquoi Bay whitefish were exploited or at least disturbed to some extent. The facts that a few very old individuals were present in the 1930 collection and that several age groups of this sample were, as in the 1931 fish, approximately equal in abundance (see males, age-groups III, VI, VIII, X) point strongly to the probability that the Missisquoi Bay population had been disturbed very recently, perhaps by the early seining in the fall of 1930. The Missisquoi Bay samples were not collected until October 24, although commercial seining started on October 1, and it is not improbable that the few old and big fish were removed before our samples were taken, thereby disturbing

the original frequency distribution of the population.

Because of this apparent disturbance each year's collection is treated separately even though both samples may represent the same general population in the lake. We do know that the two collections represented spawning schools at the two extremities of the lake, and other data to be presented later likewise indicate the distinctness of the two populations.

**TABLE 3. CALCULATED ANNUAL INCREMENTS AND STANDARD LENGTHS IN MILLIMETERS AND EQUIVALENT TOTAL LENGTHS IN INCHES OF LAKE CHAMPLAIN WHITEFISH**

| | Missisquoi Bay—1930 | | | | Southern Lake Champlain—1931 | | | |
|---|---|---|---|---|---|---|---|---|
| Year of life | Number of individuals | Increment | Standard length | Equivalent total length | Number of individuals | Increment | Standard length | Equivalent total length |
| 1 | 120 | 117 | 117 | 5.5 | 175 | 114 | 114 | 5.3 |
| 2 | 120 | 90 | 207 | 9.7 | 175 | 100 | 224 | 10.5 |
| 3 | 117 | 70 | 277 | 13.0 | 175 | 82 | 306 | 14.3 |
| 4 | 112 | 58 | 335 | 15.7 | 170 | 54 | 360 | 16.9 |
| 5 | 96 | 37 | 372 | 17.4 | 164 | 34 | 394 | 18.3 |
| 6 | 93 | 28 | 400 | 18.7 | 147 | 20 | 414 | 19.3 |
| 7 | 83 | 21 | 421 | 19.7 | 137 | 17 | 431 | 20.2 |
| 8 | 44 | 17 | 438 | 20.5 | 117 | 14 | 444 | 20.8 |
| 9 | 27 | 16 | 454 | 21.3 | 96 | 14 | 458 | 21.5 |
| 10 | 23 | 12 | 466 | 21.8 | 73 | 11 | 469 | 22.0 |
| 11 | 15 | 14 | 480 | 22.5 | 52 | 11 | 480 | 22.5 |
| 12 | 12 | 12 | 492 | 23.0 | 34 | 9 | 489 | 22.9 |
| 13 | 4 | 11 | 503 | 23.4 | 19 | 9 | 498 | 23.3 |
| 14 | 2 | 10 | 513 | 23.8 | 13 | 9 | 507 | 23.6 |
| 15 | 2 | 9 | 522 | 24.2 | 10 | 8 | 515 | 23.9 |
| 16 | 2 | 8 | 530 | 24.6 | 5 | 6 | 521 | 24.2 |
| 17 | 1 | 9 | 539 | 25.0 | 2 | 6 | 526 | 24.4 |

## Growth, Length-Weight Relationship, and Coefficient of Condition

Table 3 shows for each year's collection of whitefish, sexes combined, the average calculated length and increment in length in millimeters attained during each year of life, together with the equivalent total lengths obtained by means of the conversion factors shown on page 161. The number of specimens was too few in most of the age groups to justify the presentation of the detailed tables of computed growth data arranged by age groups, and a comparison of the calculated data arranged according to sex revealed no significant differences. Hence the data of all age groups and of the sexes were combined to obtain a general growth curve (Figure 2). The data and the figure show that after the first year the southern Lake Champlain whitefish averaged larger than the Missisquoi Bay specimens at corresponding ages until the eleventh year, when the fish of both localities reached the same length; in the twelfth and later years the Missisquoi Bay whitefish averaged larger. It is of interest to note from the growth increments that after the third year the Missisquoi Bay specimens grew consistently more rapidly than did the southern Lake Champlain fish. This difference in growth rate was not associated with the larger number of old fish taken in 1931, since

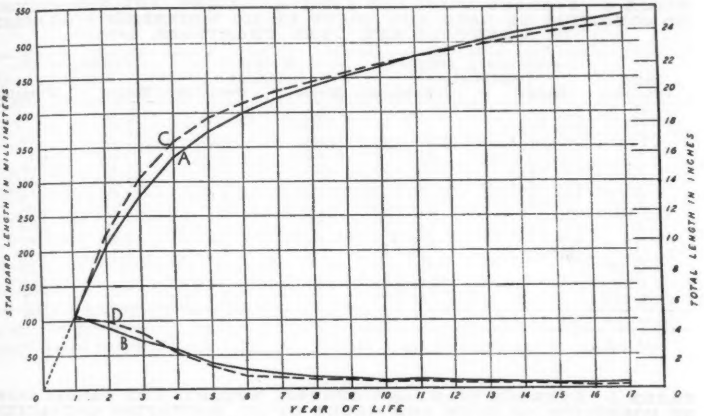


Figure 2.—Calculated length and annual increment curves of Lake Champlain whitefish. Missisquoi Bay, A = calculated lengths, B = increments; Southern Lake Champlain, C = calculated lengths, D = increments

the computed growth of these larger fish averaged better than normal. The difference is perhaps indicative of distinct populations.

In order to determine the approximate average weight of the males and females at each year of life the data of Table 1 showing the length-weight relationship may be consulted.

Tables 4 and 5 give for each age group and for each sex the average standard length and average weight at capture, and the coefficient of condition. It may be observed that in each collection the females tend to average heavier (and usually somewhat longer) than the males at corresponding ages even though their average lengths are nearly the same. That the females actually tend to be heavier than the males at corresponding lengths is indicated by the length-weight data of Table 1. The data of Tables 4 and 5 also corroborate the previous conclusion that both males and females of southern Lake Champlain averaged longer and weighed more than those of Missisquoi Bay at corresponding ages, again pointing to the distinctness of the two populations.

The coefficient of condition,[2] K, did not vary consistently in any one direction with the age groups. Neither did K show any correlation with length of fish as was determined by the analysis of a detailed table in which the coefficients were arranged by 10-millimeter intervals of fish length. The average K values did, however, vary with sex and locality. The coefficients averaged higher in the females

[2] $K = \dfrac{W \times 10^5}{L^3}$; W = weight in grams, L = standard length in millimeters.

TABLE 4. AVERAGE STANDARD LENGTH, WEIGHT, AND COEFFICIENT OF CONDITION OF EACH AGE GROUP OF 120 WHITEFISH COLLECTED IN MISSISQUOI BAY, LAKE CHAMPLAIN, 1930.

| Age group | Standard length (millimeters)[1] Males | Standard length (millimeters)[1] Females | Weight (pounds) Males | Weight (pounds) Females | Coefficient of condition Males | Coefficient of condition Females |
|---|---|---|---|---|---|---|
| II | 311 (3) | .. | 1.0 | .. | 1.55 | .. |
| III | 349 (5) | .. | 1.6 | .. | 1.70 | |
| IV | 372 (13) | 375 (3) | 1.8 | 2.2 | 1.59 | 1.90 |
| V | 398 (2) | 410 (1) | 2.2 | 2.7 | 1.55 | 1.67 |
| VI | 421 (7) | 414 (3) | 2.5 | 2.6 | 1.50 | 1.64 |
| VII | 433 (17) | 439 (22) | 2.9 | 3.1 | 1.65 | 1.63 |
| VIII | 429 (5) | 450 (12) | 3.0 | 3.6 | 1.73 | 1.72 |
| IX | 498 (1) | 446 (3) | 4.0 | 3.3 | 1.47 | 1.69 |
| X | 471 (5) | 487 (3) | 3.7 | 4.2 | 1.60 | 1.67 |
| XI | 458 (1) | 480 (2) | 3.1 | 3.9 | 1.48 | 1.60 |
| XII | 506 (2) | 490 (6) | 5.0 | 4.6 | 1.72 | 1.77 |
| XIII | .. | 512 (2) | .. | 5.5 | .. | 1.85 |
| XVI | .. | 516 (1) | .. | 5.5 | .. | 1.81 |
| XVII | | 522 (1) | .. | 5.4 | .. | 1.73 |
| Average | 411 (61) | 451 (59) | 2.6 | 3.5 | 1.62 | 1.69 |

[1]Numbers of individuals represented by averages are shown in parentheses.

TABLE 5. AVERAGE STANDARD LENGTH, WEIGHT, AND COEFFICIENT OF CONDITION OF EACH AGE GROUP OF 175 WHITEFISH COLLECTED IN SOUTHERN LAKE CHAMPLAIN, 1931.

| Age group | Standard length (millimeters)[1] Males | Standard length (millimeters)[1] Females | Weight (pounds) Males | Weight (pounds) Females | Coefficient of condition Males | Coefficient of condition Females |
|---|---|---|---|---|---|---|
| III | 333 (5) | .. | 1.3 | .. | 1.58 | |
| IV | 410 (1) | 386 (5) | 2.3 | 2.2 | 1.54 | 1.69 |
| V | 409 (11) | 395 (6) | 2.4 | 2.6 | 1.66 | 1.92 |
| VI | 432 (3) | 420 (7) | 3.0 | 3.0 | 1.70 | 1.81 |
| VII | 428 (9) | 446 (11) | 3.0 | 3.7 | 1.76 | 1.88 |
| VIII | 443 (10) | 454 (11) | 3.4 | 3.9 | 1.73 | 1.87 |
| IX | 453 (14) | 473 (9) | 3.5 | 4.1 | 1.76 | 1.77 |
| X | 473 (13) | 484 (8) | 4.1 | 4.5 | 1.74 | 1.80 |
| XI | 487 (11) | 490 (7) | 4.2 | 4.9 | 1.68 | 1.89 |
| XII | 488 (12) | 487 (3) | 4.6 | 5.2 | 1.74 | 2.06 |
| XIII | 498 (4) | 510 (2) | 4.6 | 5.0 | 1.73 | 1.71 |
| XIV | 480 (1) | 518 (2) | 4.0 | 5.5 | 1.69 | 1.80 |
| XV | 545 (1) | 500 (4) | 5.4 | 5.1 | 1.51 | 1.84 |
| XVI | 540 (1) | 530 (2) | 6.3 | 4.9 | 1.83 | 1.77 |
| XVII | 525 (2) | .. | 5.4 | .. | 1.71 | .. |
| Average | 454 (98) | 458 (77) | 3.6 | 4.0 | 1.71 | 1.84 |

[1]Numbers of individuals represented by averages are shown in parentheses.

(1.69 and 1.84) than in the males (1.62 and 1.71) and in the whitefish from southern Lake Champlain (1.71 and 1.84) than in those from Missisquoi Bay (1.62 and 1.69). These differences in relative heaviness of the fish of the two localities may be further evidences of distinct populations, although the value of K may vary with calendar years in a single population.

## Relationship Between Standard and Total Lengths

Because scientific methods require the measurement of standard (body) length in millimeters and legal size limits are usually expressed in terms of total length in inches, a knowledge of the mathematical relationship between the two lengths is important in the event that these or other data on the Lake Champlain whitefish may

be used for practical purposes. The relationship of standard length to total length, (S.L./T.L.), was determined for each fish. The results were averaged by 10-millimeter frequency groups for males and females. No differences related to sex were found and therefore averages were calculated for both sexes combined. There was no consistent change in the relationship with the increase in the size of the fish until a length of 500 millimeters was reached, when the ratios increased. For 257 whitefish from 300 to 499 millimeters in standard length (14 and 23.4 inches total length) the S.L./T.L. ratio averaged 0.840, and the reciprocal (T.L./S.L.) was 1.19. For thirty-six whitefish from 500 to 559 millimeters in standard length (23.5 and 26 inches total length) the S.L./T.L. ratio averaged 0.850, and the reciprocal (T.L./S.L.) was 1.18. To convert standard lengths to total lengths, the former is multiplied by the T.L./S.L. ratio, and the S.L./T.L. ratio is used as a multiplier to convert total lengths to standard lengths.

## Feeding Habits

The 141 stomachs collected in southern Lake Champlain in 1931, during the period October 28 to November 9, indicate that autumn is a season of reduced feeding activities for only 20 (14.2 per cent) of the stomachs contained food and 121 (85.8 per cent) were void. Since the fish were all taken with a seine and stomachs were removed immediately after capture, confinement and post-mortem digestion were not factors in causing the high percentage of void stomachs, but the approach of the spawning season during which most fishes cease feeding may have been the dominant factor. The stomachs examined were removed from fish with a size range of 14.8 to 26.2 (average 21.4) inches total length, the equivalent of 315 to 553 (average 457) millimeters standard length.

There were no significant local differences in feeding habits in the area represented by the collections (Larrabee's Landing to the Crown Point ferry landing, located on the Vermont shore, about 13 miles apart). There were likewise no consistent differences in feeding habits which could be correlated with the size of the individual.

The food of the whitefish was almost exclusively invertebrates (99.1 per cent), and small molluscs made up 92.8 per cent of all of the stomach contents (Table 6). The Amnicolidae, represented by at least two genera, accounted for 87.0 per cent of the identifiable molluscs, and the genera *Amnicola* and *Gyraulus* made up 28.7 and 56.4 per cent respectively of the total volume of food. The second family of molluscs, the Sphaeriidae, comprised only 3.5 per cent of the food and included at least two genera, *Sphaerium* and *Musculium*.

Insects and insect larvae, so finely divided that identification even to family was sometimes impossible, made up 6.4 per cent of the food. These insects were probably largely mayfly nymphs and larvae. It was not possible to obtain a volumetric determination of

**TABLE 6. SUMMARY OF THE QUALITATIVE AND QUANTITATIVE ANALYSES OF THE STOMACH CONTENTS OF 141 LAKE CHAMPLAIN WHITEFISH COLLECTED OCTOBER 28-NOVEMBER 9, 1931.**

| Item | | Percentage of total volume of all food | Percentage of number of stomachs containing food in which the item was found |
|---|---|---|---|
| Number examined | 141 | | |
| Number void (85.8 per cent) | 121 | | |
| Number containing food (14.2 per cent) | 20 | | |
| Average total length of fish (in.) | 21.4 | | |
| Minimum total length (in.) | 14.8 | | |
| Maximum total length (in.) | 26.2 | | |
| Composition of food: | | | |
| Invertebrates | | 99.1 | 100 |
| Molluscs | | 92.8 | 100 |
| Amnicolidae | | 87.0 | 75 |
| *Amnicola* sp. | | 28.7 | 25 |
| *Gyraulus* (*Valvata*) sp. | | 56.4 | 15 |
| Sphaeriidae | | 3.5 | 45 |
| *Sphaerium* sp. | | 0.1 | 15 |
| *Musculium* sp. | | 0.6 | 30 |
| Insects | | 6.4 | 25 |
| Ephemeridae | | [1]4.0 | 10 |
| *Hexagenia* sp. | | [2] | 10 |
| Fish eggs | | 0.2 | 5 |
| Plants | | 0.2 | 15 |
| Inorganic debris | | 0.5 | 10 |

[1]Estimated.
[2]Less than 0.1.

their bulk, but it is estimated that of the 6.4 per cent approximately 4.0 per cent were Ephemeridae. Only a single complete individual of the genus *Hexagenia* and a portion of another were identified.

Fish eggs, which represented 0.2 per cent of the total volume of food, were found in 5 per cent of the stomachs which contained food. The finely divided plant material was equally abundant (0.2 per cent). Neither item can be considered important. Inorganic debris —minute stones, sand, and mud—made up 0.5 per cent of the volume of the stomach contents. This material was probably taken in accidentally along with the molluscs.

Our results agree with Rimsky-Korsakoff's (1930) analyses of the stomach contents of twelve whitefish taken in Lake Champlain during the summer of 1929. During the summer months, however, the food was slightly more diversified although it was composed almost exclusively of molluscs and aquatic insects. Amphipods were taken in the summer but did not occur in the stomachs examined by us.

A summary of the main conclusions reached by this study may be found in the abstract at the beginning of the paper.

## Literature Cited

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# A STUDY OF THE MIGRATION OF THE WALL-EYED PIKE (*STIZOSTEDION VITREUM*) IN WATERS OF THE CHIPPEWA NATIONAL FOREST, MINNESOTA

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## INTRODUCTION

In 1937 the U. S. Forest Service undertook a fish migration study on Lake Winnibigoshish located in the Chippewa National Forest in north central Minnesota. The purpose of the project was to determine the distribution of wall-eyed pike (*Stizostedion vitreum*) after spawning, the extent to which wall-eyed pike returned to the same spawning grounds each year, and the mortality and population of this species, and to supplement the information obtained by the University of Minnesota concerning the growth rate of wall-eyed pike. As a part of this investigation, the Forest Service has been conducting a study of fish yield in Lake Winnibigoshish in cooperation with the resort owners and the Minnesota Conservation Department.

Lake Winnibigoshish covers an area of approximately 77 square miles. Dr. Samuel Eddy, Associate Professor of Zoology at the University of Minnesota, made the following statement concerning the general conditions in the lake:

"Lake Winnibigoshish is one of the most productive lakes in northern Minnesota, according to our surveys. Our net catches show only three species of fish to be predominant in this lake. These are the common sucker (*Catostomus commersonii*), the pickerel (*Esox lucius*), and the wall-eyed pike. Each of these fish is approximately equal in abundance. Lake Winnibigoshish has one of the largest wall-eyed pike populations of any lake we have surveyed in Minnesota. The populations of the other two species of predominant fish are surpassed in many other lakes."

## METHOD

The method followed in this study consisted of tagging male fish captured in connection with egg stripping operations conducted by the Department of Conservation to supply the Little Cut Foot Sioux hatchery located adjacent to Lake Winnibigoshish. In 1938 a limited number of female fish also were tagged. The fish were netted at the inlets of the two principal streams feeding Lake Winnibigoshish—Cut Foot Sioux and Third River.

Wall-eyed pike were taken from the State trap nets and placed in a tub of water, four or five at a time. They were taken from the tub one at a time and were always handled with canvas gloves. The fish was then turned belly up and its mouth opened ready to receive the tag. The tag was then placed around the lower jaw and clinched by

means of specially designed pliers. When closed, the tag measures 1 by 0.35 by 0.30 inch. Immediately after tagging, the fish was measured to the nearest one-half inch on a measuring board and released into the lake. The measurement (commonly known as the standard or body length) was taken from the tip of the snout to the end of the body or scaly portion of the fish (excluding the tail). The entire tagging process takes only a few seconds and, with a little practice, over 100 fish can be tagged per hour. A C.C.C. enrollee was employed to record the tag numbers and the lengths of the fish.

## Data Collected in 1937

From April 27 to May 4, 1937, there were 2,637 wall-eyed pike tagged with jaw tags, 542 of which were marked and released at the outlet of Little Cut Foot Sioux Lake, Township 147 North, Range 27 West, and 2,095 tagged and released at the outlet of Dixon Lake, Township 148 North, Range 28 West. These two lakes empty into First and Third Rivers respectively, which in turn discharge into Lake Winnibigoshish.

The fish were tagged in cooperation with the State Conservation Department. All but twenty of the fish tagged were males, as the hatchery superintendent did not wish to subject the females to both stripping and tagging. A record of standard length, sex, tag number, date, and locality where tagged was kept of each fish and placed on a card-index form.

Only 542 fish were tagged at Little Cut Foot Sioux Lake due to the fact that the water was warming up so fast that the fish had to be hurried through the nets. Acknowledgment should be made to

**TABLE 1. NUMBER OF WALL-EYED PIKE TAGGED AND NUMBER AND PERCENTAGE RECAPTURED DURING 1937**

| Item | May 15 to June 15 | June 16 to August 15 | August 16 to December 31 | Dates Unknown | Total |
|---|---|---|---|---|---|
| Number of fish caught | 175 | 112 | 44 | 14 | 345 |
| Total number of fish tagged | ---- | ---- | ---- | ---- | 2,637 |
| Percentage of tagged fish caught and reported | 6.7 | 4.2 | 1.7 | 0.5 | 13.1 |
| Total number of fish tagged at Little Cut Foot Sioux Lake | ---- | ---- | ---- | ---- | 542 |
| Percentage of fish caught which were tagged at Little Cut Foot Sioux Lake | 7.0 | 3.9 | 2.2 | 0.4 | 13.1 |
| Total number of fish tagged at Dixon Lake | ---- | ---- | ---- | ---- | 2,095 |
| Percentage of fish caught which were tagged at Dixon Lake | 6.7 | 4.3 | 1.5 | 0.5 | 13.1 |

Mr. Albin Anderson, superintendent, and to his crew at the Little Cut Foot Sioux hatchery for their assistance and especially to Mr. Ted Matheson, of Deer River, and Mr. Frank Hendricks, of Ball Club, who handled the 2,095 fish at Dixon Lake.

Resort owners were contacted and each given a large map of Lake Winnibigoshish and adjoining lakes on which to place the numbers of recovered tags. Also, several thousand mimeographed letter-sized sheets were distributed for individual fishermen's reports. Signs were erected at all roads by which fishermen could reach the lakes without contacting resort owners. These signs called attention to the presence of tagged fish in the waters, and gave information concerning the purpose of the study and the procedure to be followed in reporting the capture of a tagged fish.

Results of the study up until December 31, 1937, when all fishing for game fish was prohibited in Minnesota, are presented in Table 1. The percentages of recaptures are the same for the fish tagged at the two stations. This would seem to indicate that a very large majority of the tagged fish caught was reported because the same per cent of tagged fish was caught in each case whereas the number tagged in Dixon Lake was 3.8 times as large as that tagged at Little Cut Foot Sioux Lake.

The average number of tagged fish caught per day for the four periods is as follows:

| | |
|---|---|
| May 15 to June 15 (32 days) | 5.47 |
| June 16 to August 15 (61 days) | 1.84 |
| August 16 to December 31 (138 days) | 0.32 |
| May 15-December 31 (231 days) | 1.43 |

The above data coincide with the results of our fish-yield study for Little Cut Foot Sioux Lake, which showed that the largest catch of wall-eyed pike in pounds per man-hour occurred between May 15 and June 5. After June 5 the catch dropped to almost nothing in August in Little Cut Foot Sioux Lake, which decrease was also shown by our data.

In Table 1 it may be seen that on both lakes the greatest returns occurred during the first period, a progressive decline in the second and third periods, and almost no returns at all in the last period. Actually most of the tagged fish caught in these two lakes were taken before June 1. This clearly indicates that the fish caught very early in the season are the ones remaining in the lake from the spawning run, but by June 1 most of the spawners have gone back into Lake Winnibigoshish. If the open season on Little Cut Foot Sioux and Dixon Lakes were delayed two weeks, most of the spawned fish would be protected. This is a thought for future management of the spawning areas.

Many of the recaptures reported for the period, May 15 to June 15, were not dated but on the opening day of the fishing season sev-

eral tagged fish were caught in Dixon and Little Cut Foot Sioux Lakes and one in Big Cut Foot Sioux Lake. This latter fish was tagged in Little Cut Foot Sioux Lake on April 28, and was through spawning and returned to Big Cut Foot Sioux Lake eighteen days later.

The first definite record of a tagged fish caught in Lake Winnibigoshish was on May 18. This fish was tagged in Little Cut Foot Sioux on April 29, and twenty days later was caught near the mouth of Third River, 13 miles away.

The next records were on May 26, when two tags were recovered. Strange as it may seem, one of these fish was tagged in Little Cut Foot Sioux Lake while the other was tagged in Dixon Lake, yet both were caught close to each other near the "Highbanks" along the east central shore of Winnibigoshish. The Little Cut Foot Sioux Lake fish had travelled at least 10 miles while the Dixon Lake fish had travelled at least 18 miles and both were tagged on the same date, April 29.

On May 30, five tagged fish were caught in Winnibigoshish between Raven's point and Pidgeon River. One of these was tagged in Little Cut Foot Sioux but caught in the mouth of Third River. Another was caught in the southwest corner of the lake on June 4. Both of these fish were tagged on May 1 at Dixon Lake about 7 miles away. No definite records of fish caught in the south end of Winnibigoshish appeared until June 5.

From these data it would seem that the wall-eyed pike were fairly well distributed throughout Lake Winnibigoshish by June 5, and by June 15 practically all of the original population had returned to the big lake.

The average standard length of 543 fish tagged in Little Cut Foot Sioux Lake was 16.0 inches, and all were males. In Dixon Lake 20 females averaged 16.0 inches, whereas the 2,075 males which were tagged averaged only 14.9 inches. According to growth studies made by Dr. Eddy in 1936 on 130 wall-eyed pike taken in Lake Winnibigoshish, a 14-inch fish would be 5 years old and a 16-inch fish about 6 years. His figures showed an average annual growth of 2.8 inches. It will be interesting to check this figure when measurements are made during the spring of 1938 of fish which were tagged exactly one year previously.

The general opinion of local fishermen is that during the first part of the season only the smaller wall-eyed pike can be caught, but for the period May 15 to June 15 the average length of fish caught, which were tagged in Dixon Lake, was 15.2 inches, or 0.3 inch greater than the average of all tagged fish from Dixon Lake. However, in Little Cut Foot Sioux Lake the average of thirty-six male pike caught from May 15 to June 15 was only 15.1 inches, or almost an inch smaller than the average of all males tagged in that locality.

## Summary of 1937 Data

1. Thirteen and one-tenth per cent of the 2,637 wall-eyed pike tagged on Little Cut Foot Sioux Lake and Dixon Lake were caught and reported during 1937.

2. Fifty-two per cent of the tagged fish taken were caught the first thirty days of the fishing season, from May 15 to June 15.

3. Nearly the same percentage of recovery was made of fish tagged on the two lakes, indicating excellent cooperation of resort owners and fishermen.

4. Wall-eyed pike seemed for the most part to have completed spawning by June 1. This indicates that the wall-eyed pike and pickerel fishing season should be closed until June 1 in all lakes where wall-eyed pike spawn, but following that date fishing should be allowed so as to reduce the abundance of the larger fish and give the fry and fingerlings a better chance for survival and growth.

5. Wall-eyed pike seem to range extensively throughout Lake Winnibigoshish and distribute themselves generally in the entire lake a short time after spawning.

6. The average standard length of males was 16.0 inches in Little Cut Foot Sioux and 14.9 in Dixon Lake, or an average for all male wall-eyed pike from Winnibigoshish of 15.1 inches. These fish would probably be about 5 years old.

7. No reports from any source have been received to the effect that the fish were harmed in any way by the tags.

## Data Collected in 1938

The run of wall-eyed pike during the spring of 1938 began about March 28, which was much earlier than usual. The warm weather in March and the first part of April, which caused the early run, only lasted until the middle of April, when a siege of cold, rainy weather set in which continued until early in June. This protracted cold period caused the spawning season to extend over a longer period than usual. In addition, the run seemed to be smaller than usual at the localities in Cut Foot Sioux and Third River where nets were set.

Exactly 300 tagged fish were recovered in the nets between March 29 and April 26. The total number of fish tagged in 1937 was 2,637 and the number caught by fishermen in 1937 was 345. This left 2,292 tagged fish in the water if all tagged fish which were caught were reported and none was lost through natural causes, which is, of course, a false assumption. However, we can actually account for 645 tagged fish. What has become of the remaining 1,988 or 75 per cent of the original number of tagged fish cannot be determined at present.

It is interesting to note that 300 or 13.1 per cent of the tagged fish remaining after the 345 were caught last summer (1937) returned

to the nets where they were tagged last year. This 13.1 per cent happens to be exactly the same percentage that was caught by fishermen in 1937.

The most obvious reason why only a small percentage of fish returned to the two spawning places which they used last year is the high water level. The water from Lake Winnibigoshish was much higher than usual during the spring of 1938 and had backed up into all tributary streams and rivers and flooded all meadows within several miles of the lake shore. This opened up vast new spawning areas, and no doubt had a marked effect in reducing the run at Third River and Little Cut Foot Sioux Lake. The heaviest run of tagged fish occurred between April 10 and 20, whereas in 1937 the heaviest run of wall-eyed pike took place after May 1.

Of the 300 tagged fish which returned to the nets, 134 were recorded at the Little Cut Foot Sioux nets and 166 at the Third River nets. Of the 134 recaptured at Little Cut Foot Sioux, 111 were tagged there in 1937, whereas only 23 were tagged at Third River in 1937. Thus, of the 134 tagged fish which were recovered at the Little Cut Foot Sioux nets in 1938, 83 per cent returned to the same spawning area they used in 1937, while 17 per cent were fish that had spawned in Dixon Lake in 1937. Of the 166 recovered at the Third River nets, 162 or 97 per cent were tagged there in 1937 while only 3 per cent had been tagged at Little Cut Foot Sioux.

Thus, of the fish recovered in the 1938 run, 90 per cent returned to the same place at which they were tagged in 1937 and only 10 per cent changed spawning areas. It seems logical, therefore, to assume that most of the wall-eyed pike return to the same spawning beds year after year. However, if this were true we would also have to assume that the remaining 1,988 tagged but unrecovered fish were destroyed by predators, illegal fishing, etc., which does not seem possible.

Mr. Albin Anderson, who is in charge of the Little Cut Foot Sioux hatchery, believes that the majority of the wall-eyed pike remain in Lake Winnibigoshish to spawn each year. To support this assertion, he stated that one resort owner reported the capture of 10,000 wall-eyed pike at his resort in 1937, which represents more than the annual run at the Little Cut Foot Sioux nets.

Studies of fish yield now being conducted at all resorts and landings at Lake Winnibigoshish, supplemented by further data from the wall-eyed pike tagging returns, should answer the questions as to whether or not the wall-eyes return to the same spawning areas each year; whether or not most of them stay in the big lake to spawn; and what happened to the fish not recovered by the spring of 1938.

With only inadequate measurements to support the conclusion, it seems safe to say that when male wall-eyed pike reach a size of 15 or 16 inches, they have attained sexual maturity and do not normally grow more than an inch or two in a year.

Some 346 male wall-eyed pike were tagged on April 12, 1938, at Little Cut Foot Sioux Lake. The fish were tagged by the writer and measured by J. B. Moyle, State Biologist.

### Summary of 1938 Data

1. The 1938 wall-eyed pike run started about March 28 and ended about May 1.
2. Three hundred wall-eyed pike tagged in 1937 were recovered during the spring run in 1938 between the dates of March 29 and April 26.
3. Seventy-five per cent of the original 2,637 tagged fish have not yet been reported.
4. Ninety per cent of the fish recovered during the run of 1938 had returned to the same locations where they were tagged during the run of 1937.
5. Studies of the fish yield and further checking of recovered fish are needed in order to make any conclusive deductions as to spawning habits of the wall-eyed pike of Lake Winnibigoshish. These studies are being carried on at present.
6. Measurements were taken in 1938 with sufficient accuracy to use in determining rates of growth.
7. Three hundred forty-six additional wall-eyed pike were tagged and released on April 12, 1938.

# NEW ADAPTATION OF FISH GRADER

Gustave Prevost

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The classification of speckled trout, by size, is a very important problem to consider, because of the cannibalism which is so prevalent among these fish.

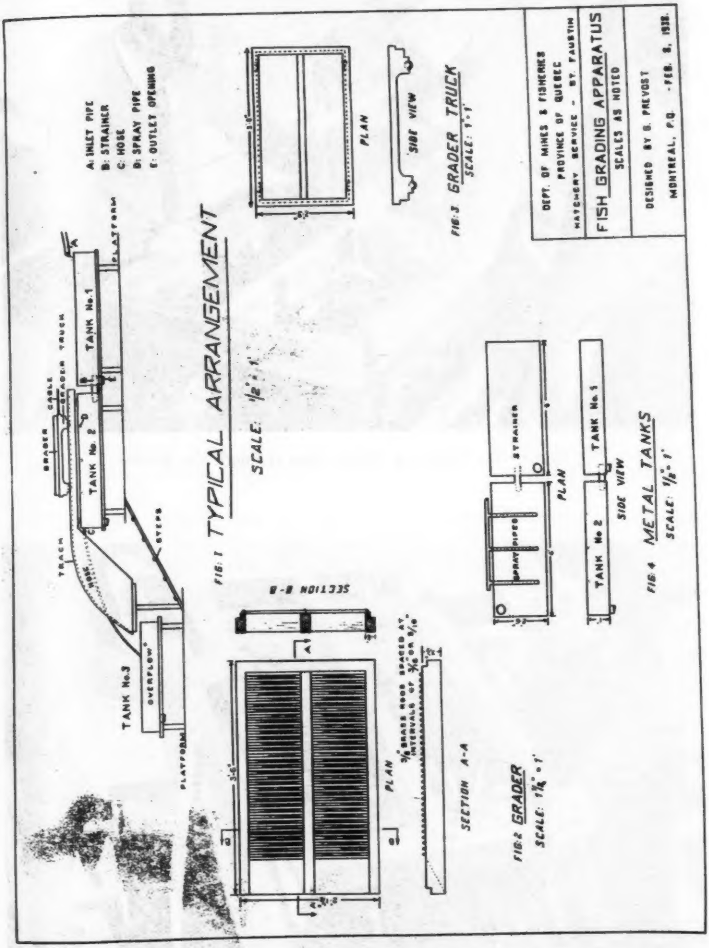
There are many well-known methods of sorting fish which I do not intend to enumerate here. The object of this paper is to present a new adaptation of a grader already commonly used in hatcheries. This grader is built in a wooden frame, and is made of bars of brass or other metal, placed at certain regular distances apart (Figure 2). The usual method of using this grader simply consists of placing it in a basin and filling it with trout. The whole unit floats on the surface. The smaller trout pass through the bars, and the larger ones remain above. This method, while very good in principle, is fairly laborious. If we place the grader on a mobile truck (Figure 1) instead of in the basin of fish, the sorting may be done much more rapidly, in the following manner.

## Description of Use of Grader

In reservoir No. 1 (Figure 1) we place the fish to be classified—about 10,000 or 15,000. The water in this reservoir is being continually renewed by means of a supply pipe (A). The water passes to tank No. 2 through strainer "B," thence to tank No. 3 through hose "C." By means of a dip-net, we remove the trout from the tank No. 1 and place them in the grader, which is divided into two compartments (Figure 2). An operator on each side helps the passage of any fish which may be caught between the bars (Figure 5). During the whole operation, the fish receives a beneficial shower by means of spray pipes (D, Figure 1 and Figure 4) placed under the grader. When all the smaller trout have passed through the grader, the truck is then moved down the incline, and the larger trout are automatically dumped into tank No. 3 (Figure 6), and the operation is completed.

The truck is returned to a horizontal position by means of a cable. Then a special kettle is placed under the drains of tanks No. 2, and No. 3, the trout are removed, and then weighed in order to determine the number present. Afterwards they are placed in separate tanks.

The advantage of this method is the rapidity with which we may classify a large number of trout—approximately 10,000 per hour.




**Figures 1 to 4.—Construction details of fish grading apparatus.**

Figure 5.—Assisting fish to pass through the grader.

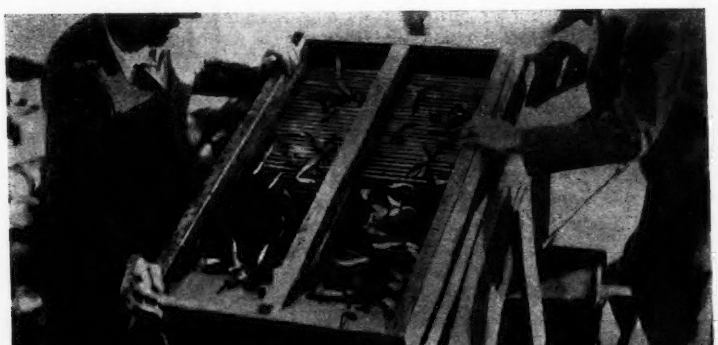


Figure 6.—Dumping the larger fish in tank No. 3.

# NOTES ON *MYXOBOLUS INORNATUS*, N. SP., A MYXOSPORIDIAN, PARASITIC IN THE BLACK BASS (*HURO FLORIDANA*, LE SUEUR)[1]

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## INTRODUCTION

A largemouth black bass fingerling preserved in formalin was sent to the U. S. Bureau of Fisheries Pathology Laboratory at Seattle, Washington, during the autumn of 1937, by a hatchery employee at Miles City, Montana. The fish exhibited several wart-like protuberances on the caudal peduncle, which aroused the curiosity of Mr. H. C. Topel, in charge of fish distribution at Miles City. He had observed the gradually increasing numbers of these lesions on the fish at this station for several years previous to 1937. Mr. Topel estimated that in 1937, 20 per cent of the adult bass were infected at the time of distribution, and lesions were noted on the fingerling and yearling stock as well.

A microscopical examination of the lesions revealed them to be subcutaneous cysts formed by an undescribed Myxosporidian that belongs to the genus *Myxobolus* and is here specifically named *inornatus*, n. sp.

Through the cooperation of the Division of Fish Culture of the U. S. Bureau of Fisheries, additional material, both living and preserved, was obtained from the Miles City hatchery for study.

## GROSS LESIONS

The cysts, as observed on living hosts, are usually located on one or both sides of the caudal peduncle. On two fish of some fifty examined, cysts were likewise found on one side of the body about one centimeter below the dorsal fin. No cysts have been observed in the internal organs. The cysts are usually ovoid in shape, quite variable in size, and actually represent an aggregation of varying numbers of smaller cysts each measuring approximately 1 by 1 by 2 millimeters and closely bound together by a connective tissue framework elaborated by the host. The cysts are located in the body musculature just below the subdermal connective tissue layer, are white in color, and show through the overlying skin sufficiently to lighten the normal olive green coloration of the host. Some congestion of the adjacent blood vessels is apparent. The exact shape of the large cysts apparently departs from the ovoid only when the pressure from the expanding component parts forces the parasites along the line of least resistance from the surrounding tissues. The typical ovoid cyst measures about 7 millimeters in length, 6 millimeters in width, and

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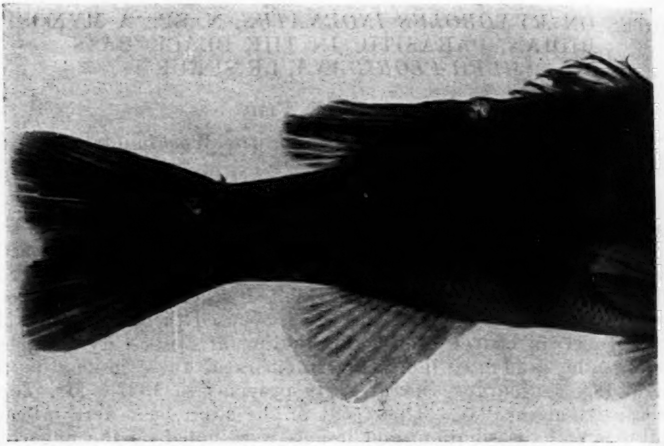

Figure 1.—Gross lesions formed by *Myxobolus inoratus* on the caudal peduncle and body surface of fingerling largemouth black bass. Approximately life size.

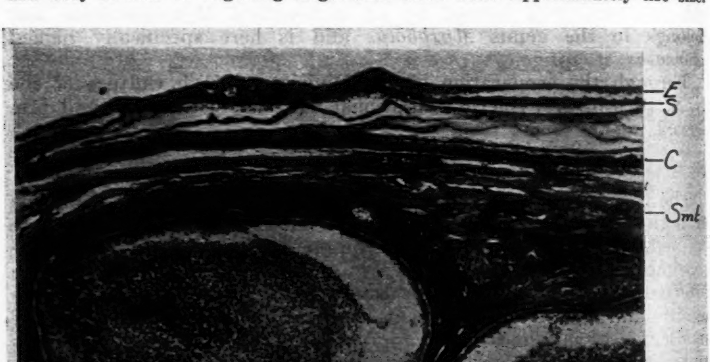


Figure 2.—Microscopic lesions formed by *Myxobolus inornatus.* Section through caudal peduncle, hematoxylin and eosin, X 60. E — epithelium; S — scale; C — corium; Smt. — Subcutaneous muscular tissue; P — parasitic cyst.

3 millimeters in thickness. The overlying skin usually exhibits considerable tension. Figure 1 shows typical lesions of *M. inoratus*.

Through the cooperation of Mr. J. T. Barnaby, of the U. S. Bureau of Fisheries, three 3½-inch fingerling fish, each with well-developed lesions on their caudal peduncle, were placed in a balanced aquarium on October 25, 1937, for observations on subsequent development of the lesions. During the week of November 5, one of these fish sloughed the cysts. The cysts ruptured through the overlying skin following a marked swelling of the infected area, accompanied by some inflammation. The resulting ulcer eventually healed smoothly and completely, leaving no evidence of the infection. Sometime between November 15 and December 31, the remaining two infected fish likewise sloughed the parasitic cysts and the perforated areas healed as uneventfully as had those on the first fish. These three fingerlings were subsequently kept in the same aquarium without change of the water in order to determine if reinfection could be caused by spores liberated by the ruptured cysts. The initial infestation of these fish must have developed within a period of four months between the time of hatching and distribution. An equal period of time has elapsed since the cysts were sloughed (which provided the first opportunity for reinfection), yet at the time this paper was written no evidence of reinfestation has been observed.

## The Parasite

The cysts were filled with a white viscid fluid which, upon microscopical examination, were found to contain only liquefied parasites and spores. Large numbers of spores were observed in each cyst and, aside from a relatively few which were still paired in the diaphanous spore envelope, all spores appeared fully mature. The trophozoite stages in the life history of this organism were not apparent in the material studied.

The spores, typical of the genus *Myxobolus*, are ovoid with the largest diameter coinciding with the sutural plane, possess an iodinophilous vacuole, and are without any posterior process or tail. Within the genus *Myxobolus*, the new species most closely resembles *M. permangus* Wegener, and *M. carassii* Klokacewa. However, *M. inornatus* is significantly smaller than any one of these related species.

The spores of *M. inornatus* are composed of two symmetric valves which meet in a straight line along a narrow sutural ridge which is usually thrown into a series of five to eight lateral folds. The valves enclose two polar capsules of approximately equal dimensions and the binucleated sporoplasm. The sporoplasm appears homogeneous in texture and contains a large vacuole which, either in living or formalin preserved material, stains a deep chestnut brown upon the addition of dilute iodine solution. Biometric data on the spores of *M. inornatus* are given in Table 1.

**TABLE 1. BIOMETRIC DATA ON SPORES OF *MYXOBOLUS INORNATUS***
**All dimensions in microns**

| Item | 100 living spores | | 100 formalin preserved spores | | 100 stained and mounted spores | |
|---|---|---|---|---|---|---|
| Length of spore | M. | 12.3955 | M. | 12.308 | M. | 11.741 |
| | S.E. | 0.0883 | S.E. | 0.0636 | S.E. | 0.0603 |
| | C.V. | 7.127 | C.V. | 5.174 | C.V. | 5.156 |
| Breadth of spore | M. | 8.241 | M. | 8.1607 | M. | 7.262 |
| | S.E. | 0.0502 | S.E. | 0.05265 | S.E. | 0.0385 |
| | C.V. | 6.0955 | C.V. | 6.496 | C.V. | 5.326 |
| [1]Thickness of spore | M. | 5.8869 | — | — | — | — |
| | S.E. | 0.05256 | — | — | — | — |
| | C.V. | 5.8546 | — | — | — | — |
| Length of longer polar capsule | M. | 5.1268 | M. | 5.0427 | — | — |
| | S.E. | 0.04593 | S.E. | 0.0402 | — | — |
| | C.V. | 8.959 | C.V. | 7.971 | — | — |
| Breadth of longer polar capsule | M. | 2.486 | M. | 2.257 | — | — |
| | S.E. | 0.02485 | S.E. | 0.0242 | — | — |
| | C.V. | 9.994 | C.V. | 9.046 | — | — |
| Length of shorter polar capsule | M. | 4.8774 | M. | 4.7147 | — | — |
| | S.E. | 0.04202 | S.E. | 0.04121 | — | — |
| | C.V. | 8.615 | C.V. | 8.7415 | — | — |
| Breadth of shorter polar capsule | M. | 2.4527 | M. | 2.244 | — | — |
| | S.E. | 0.02637 | S.E. | 0.0254 | — | — |
| | C.V. | 10.75 | C.V. | 11.307 | — | |

M.—Arithmetic mean.
S.E.—Standard error.
C.V.—Coefficient of variability.
[1]Based on forty-three measurements only.

## Pathology

Sections through areas of infected tissue show the large cysts formed by *M. inornatus* that occupy an area normally filled by the body musculature. As there is little compression of the muscle bundles immediately surrounding the invaded area, it is concluded that some muscle destruction must occur during the development of the parasite. In all tissues observed, the parasite was immediately encapsulated by a band of scar tissue laid down by the host. Between the scar tissue and the surrounding normal musculature was a highly vascular area of relatively compact tissue composed chiefly of mononuclear wandering cells and some connective tissue strands. Some deposits of blood pigment, indicative of previous hemorrhage, were also observed in this area. Mononuclear wandering cells were very abundant among the surrounding muscle bundles.

The entire defense of the host apparently was a successful attempt to wall off the invading parasite with connective tissue. Figure 2 is a photomicrograph of a section through a cyst showing the arrangement of the component smaller cysts, their relation to the tissues of the host, and the connective tissue band surrounding the parasites.

## Discussion

In view of the apparent predilection of *M. inornatus* for the subcutaneous muscular tissue, it probably causes little more than a temporary inconvenience to the host. Certainly, no infected fish

have been found wherein the infestation could conceivably be a menace to the life of the fish. Apparently, the only damage caused by *M. inornatus* is the unsightly lesions which would be aesthetically offensive to anglers. However, from observations on the infected fingerlings confined in the aquarium, the lesions are not a permanent condition and their complete disappearance may be expected within a comparatively short time.

However serious infestations of *M. inornatus* may be from the aesthetic viewpoint, there is no reason to suspect that it is of any public health significance. Although controlled experimental evidence is lacking, nevertheless, infestations by the Myxosporidia as a group are confined to poikilothermous vertebrates, principally fishes, and there is no record of a Myxosporidian parasitizing any warm-blooded host.

Because the Myxosporidia require no intermediate host for the completion of their life cycle, the distribution of infected fish would permit the spread of the parasite into areas now free from infestation. It would, therefore, appear advisable to take suitable precautions to prevent the establishment of this parasite in bass hatcheries which might serve as active sources of infection. Under the extensive pond system of propagating bass, the environment is most congenial for the wide dissemination of any parasite requiring no intermediate host. As *M. inornatus* most probably is introduced into bass ponds by infected fish, the intensity of infection could be materially reduced, if not entirely eliminated, by the close scrutiny of every fish, both brood and forage, placed in the ponds. Any fish bearing evidence of the disease should be destroyed.

## Summary

The morphology, taxonomy, gross and microscopic pathology of *Myxobolus inornatus*, n. sp., a Myxosporidian parasite of largemouth black bass (*Huro floridana*, Le Sueur) taken from the Miles City, Montana, bass hatchery are described.

This parasite is of no public health significance and is believed to be of doubtful pathogenicity—the chief damage to the host being the formation of unsightly, wart-like protuberances on the caudal peduncle. The lesions, apparently, are of temporary duration.

# SIMPLIFIED METHODS FOR THE PROLONGED TREATMENT OF FISH DISEASES[1]

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## INTRODUCTION

The prevention or control of epidemics of fish diseases by applying a disinfecting solution in a uniform concentration directly to the water supply of a fish pond or trough for a definite period of time has been exceedingly slow in development. In so far as can be determined, the original idea should be credited to Marsh and Robinson (1910). In their work on the control of algae in fish ponds by the continuous application of dilute copper sulphate solution, administered to the inflowing water supply by means of a floating syphon, they suggested this method as a possibility in the treatment of fish diseases. Following their work, this commendable idea seems to have remained quite dormant and apparently forgotten until Hess (1930) revived it twenty or more years later. This worker found that a prolonged immersion in a dilute disinfecting bath was more efficacious in removing fluke parasites from goldfish than was the customary short "hand dip" method. Kingsbury and Embody (1932) later adapted the idea of a prolonged treatment to running water by the use of a float valve for maintaining a constant level in a reservoir, resulting in a constant flow to the pond or trough to be treated. Shortly thereafter, Fish (1933) modified the floating syphon of Marsh and Robinson, as it was a simpler apparatus than that of Kingsbury and Embody.

The basic idea of prolonged treatment as a practical method for both the prevention and control of fish diseases is of great importance in that it is more effective than the hand dip method, assuming that Hess's results on goldfish are equally applicable to trout, and that it eliminates the necessity for handling the fish during treatment. Handling may be more injurious to the fish than the disease being treated. However, commendable as the idea of prolonged treatment may be, at the present time it possesses several limitations which must be obviated before the method may be regarded as perfected.

Chief among the limitations of prolonged treatment are:

1. The unknown toxicity and efficacy of disinfectants under varying factors of concentration, duration of exposure, temperature, and the chemical and organic content of the water.

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2. The fragility of the apparatus (at least, the floating syphon type which now appears to be in general use).

3. The relatively complex calculations involved in determining the proper dosage for a treatment.

4. The inherent inaccuracy of present methods, which becomes of progressively greater importance as the size of the body of water to be treated is increased.

One of the projects undertaken during the past two years at the West Coast Pathology Laboratory of the U. S. Bureau of Fisheries has been an investigation of the limitations of present methods for prolonged treatment as outlined above in an effort to find satisfactory means for overcoming their effects. This work is by no means completed, but sufficient advances have been made to warrant the publication of a progress report.

## I. Toxicity and Efficacy of Disinfectants

In the absence of suitable facilities and equipment, little progress has been made by any agency in a scientific investigation of the very pertinent subjects of the toxicity and effectiveness of any concentration of a disinfectant in the treatment of a specific disease. To date, most work has been done essentially on a "trial and error" basis, and the results are complicated by many unknown factors. A few investigators, notably Kingsbury and Embody, have made some progress in this field. All known results are summarized in Table 1 merely as a guide for those individuals who may wish to apply the disinfectants listed. At the present time, there is no valid basis for applying the results on either toxicity or efficacy obtained under one set of conditions to a different set. Therefore, a hatchery man intending to apply any disinfectant in a prolonged treatment is cautioned to proceed with care. Regardless of any report on the non-toxicity of a certain concentration of a disinfectant used elsewhere, he should always try it out on a small number of isolated fish under the particular conditions found at his own hatchery. Having definitely established the non-toxicity of the recommended concentration, he may then proceed with more confidence in applying the disinfectant to an entire trough of fish.

## II. Improvement of the Apparatus

For many reasons, the "pail and syphon" apparatus recommended by Fish (1933) has been discarded. In its place has been substituted an apparatus composed of a 3-gallon glass bottle, a small flat-bottom receptacle about 3 inches deep with a hole in the bottom (the writer uses a shellacked tin bread pan into which a ¾-inch hole has been bored), and a piece of small bore glass tubing about 3 inches long mounted in a one-hole rubber stopper of suitable size to fit snugly into the hole in the bottom of the receptacle. The component parts

TABLE 1. NON-TOXIC CONCENTRATIONS OF DISINFECTANTS

| Reagent | Reported non-toxic concentration | Time of exposure in minutes | Size and species of fish | Water temperature °F | Authority | Remarks |
|---|---|---|---|---|---|---|
| Potassium permanganate | 1 to 100,000 | 30 | -------- | -------- | Hofer | Toxicity and efficacy of potassium permanganate varies markedly with organic content of water. |
| | 1 to 150,000 | 60 | -------- | -------- | Plehn | |
| | 1 to 267,000 | 120 | goldfish | -------- | Hess | |
| | 1 to 100,000 | 60 | trout eggs | [1]—45° | Kingsbury and Embody | |
| | 1 to 125,000 | 60 | " | 46°-52° | " | |
| | 1 to 150,000 | 60 | 1-2 inch trout | —45° | " | |
| | 1 to 175,000 | 60 | " | 46°-52° | " | |
| | 1 to 75,000 | 60 | trout 3 inches and over | —38° | " | |
| | 1 to 100,000 | 60 | " | 38°-45° | " | |
| | 1 to 150,000 | 60 | " | 46°-55° | " | |
| | 1 to 175,000 | 60 | " | 55°-65° | " | |
| | 1 to 200,000 | 60 | " | 65°+ | " | |
| Copper sulphate (hydrated bluestone) | 1 to 50,000 | 60 | -------- | —45° | Kingsbury and Embody | Toxicity and efficacy of copper sulphate varies markedly with hardness of water. |
| | 1 to 75,000 | 60 | -------- | 46°-55° | " | |
| | 1 to 100,000 | 60 | | 55°+ | " | |
| | 1 to 200,000 | 60 | 2-inch chinook salmon | 46° | Fish | |
| | 1 to 300,000 | 120 | " | 48° | " | |
| 40 per cent formaldehyde (formalin) | 1 to 2,000 | 60 | -------- | 55° | Kingsbury and Embody | |
| | 1 to 2,500 | 60 | -------- | 55°-70° | " | |
| | 1 to 3,000 | 60 | -------- | 70°+ | " | |
| | 1 to 2,000 | 30 | 2-inch chinook salmon | 47° | Fish | |
| | 1 to 4,000 | 90 | " | 47° | " | |
| Chlorazene tablets (90 per per cent chloramine) | 1 to 6,000 | 30 | 2-inch chinook salmon | 45° | Fish | |
| | 1 to 12,000 | 60 | " | 45° | " | |
| | 1 to 20,000 | 120 | " | 45° | " | |
| Salt | 1 to 50 (2%) | 30 | 2-inch chinook salmon | 45° | Fish | |
| | 1 to 66 (1.5%) | 120 | " | 45° | " | |
| | 1 to 100 (1%) | [1]180+ | " | 45° | " | |
| Malachite green | 1 to 300,000 | 60 | 2-inch chinook salmon | 48° | Fish | |
| | 1 to 800,000 | 90 | " | 48° | " | |
| Boric acid | 1 to 1,000 | 360 | 2-inch chinook salmon | 50° | Fish | |

[1]A minus sign means less than and a plus sign means more than the figure given.

may be purchased for less than one dollar and when assembled, the apparatus works exceedingly well for water-flows up to 50 gallons of water per minute at dilutions of 1 to 75,000, or greater, for one hour. In addition to the parts listed above, a stand must be built (any conveniently available scrap lumber will be satisfactory) which will permit the bottle-reservoir to be readily inverted over the receptacle so that the neck of the bottle extends about one inch below the top of the receptacle. Figure 1 shows the apparatus in actual use. It should be noted that the rubber stopper bearing the glass tubing must be inserted from the inside of the receptacle so that it cannot possibly fall out during the treatment.

Only one alteration is necessary. With the apparatus set up, the small piece of glass tubing must deliver between 6,000 and 11,000 cubic centimeters per hour. This quantity can only be determined by trial and error, using water in the bottle-reservoir. A piece of glass tubing of 4 millimeters inside diameter works very satisfactorily when the bore is slightly constricted during the process of fireburning the cut ends. If more than 11,000 cubic centimeters are delivered per hour, the glass tubing should be thoroughly dried and one end held in a Bunsen flame. The bore will close slowly as the glass becomes hotter and the process may be stopped whenever the desired aperture has been reached.

For subsequent convenience in operation, it is also advisable to paint a white strip vertically on the bottle-reservoir. The strip is then calibrated by adding 6,000 cubic centimeters of water to the bottle and marking on the painted strip, by means of a common pen and India ink, the height attained by this volume of water. Two hundred fifty cubic centimeters of water is then added and the height again marked. The process is repeated until a graduated scale from 6,000 to 11,000 cubic centimeters, by 250 cubic centimeter intervals, is obtained. For permanence, it is advisable to cover the calibration marks with one or two coats of clear shellac.

## III. Calculations Involved in Operation

The calculations required for the use of this apparatus are most elementary. All calculations are based on the assumption that *only the exact amount of disinfectant delivered by the glass tubing during the period of time over which the treatment is to extend will be placed in the bottle-reservoir.* On this assumption, the weight of disinfectant to be dissolved in the bottle-reservoir for *each gallon per minute of inflowing water to be treated* is calculated by the following formula:

$$\frac{3{,}785 \times \text{Period of treatment (in minutes)}}{\text{Final concentration desired}} = \text{Grams of disinfectant to be dissolved in the bottle-reservoir for } \textit{each} \text{ gallon per minute to be treated}$$

Figure 1.—The simplified apparatus for administering prolonged treatments in actual use.

Figure 2.—Prolonged treatment by recirculation of disinfecting solution. The solution is pumped from an intake at the foot of the pond and discharged above the water surface near the upper end.

As an example—a trough receiving 7 gallons per minute is to be treated for one hour and a half at a disinfectant-concentration of 1 to 125,000:

$$\frac{3{,}785 \times 90}{125{,}000} \times 7 = 19.15$$

Assuming that the particular glass tube in use delivers 120 cubic centimeters per minute, then 19.15 grams of the disinfectant are placed in the bottle-reservoir which is then filled with water to the 10,800 cubic centimeter mark ($120 \times 90 = 10{,}800$), and the apparatus is ready for use.

At the present time, however, there seems little reason to depart, except experimentally, from the standard treatment of one hour established by Kingsbury and Embody. Therefore, the data of Table 2 are applicable to any apparatus of this type providing the amount of liquid delivered by the glass tube in one hour is placed in the bottle-reservoir.

**TABLE 2. AMOUNT OF DISINFECTANT TO BE USED TO OBTAIN VARIOUS DILUTIONS**

| Dilution | Grams of disinfectant to be dissolved in the bottle-reservoir for EACH gallon per minute inflow |
|---|---|
| 1 to 50,000 | 4.54 |
| 1 to 75,000 | 3.03 |
| 1 to 100,000 | 2.27 |
| 1 to 150,000 | 1.51 |
| 1 to 200,000 | 1.14 |
| 1 to 250,000 | 0.91 |
| 1 to 300,000 | 0.76 |
| 1 to 400,000 | 0.57 |
| 1 to 500,000 | 0.45 |

For any intermediate dilution, the number of grams of disinfectant to be dissolved in the bottle-reservoir for each gallon per minute inflow to be treated may be obtained by merely dividing 227,100 by the dilution desired. For example, a dilution of 1 to 100,000 requires $227{,}100 \div 100{,}000$ or 2.27 grams of disinfectant.

In applying a treatment with the apparatus ready for use as described above, drain the trough to the absolute minimum level compatible with the well being of the fish, place the stand on the trough so that the tube will drain directly into the inflowing water, and invert the bottle-reservoir over the receptacle. If the stand has been properly built, the bottle-reservoir will slide into a fixed position quickly and easily without spilling any of the disinfectant. It is usually advisable to have the disinfectant and the inflowing water spill from a cup or dam to assure thorough mixing. After the water in the trough has risen sufficiently to permit the fish to swim freely, the trough drain should be opened slightly for a time so that the residual water in the trough when the treatment was started will

be replaced as rapidly as possible. Immediately after the apparatus has delivered all of the disinfectant, the trough should be again drained as rapidly as possible to remove the disinfectant. The apparatus should be thoroughly washed before putting it away.

To obviate the difficulty of weighing disinfectants accurately, particularly at hatcheries where delicate scales are not available, the use of stock solutions is advised. A mark should be etched or filed on the side of a 1-gallon glass jug at the height attained by a given volume of water—usually 3,500 cubic centimeters. "Charges" of the disinfectant to be used may be accurately weighed at some central point and each hatchery supplied with a calibrated glass jug and a number of these charges. If each charge contains 118.4 grams of the disinfectant and one charge dissolved in the jug, which is then filled with pure water to the 3,500 cubic centimeter mark, each fluid ounce of the resulting stock solution will contain exactly 1 gram of the disinfectant. The hatchery man can then obtain any desired weight of disinfectant without scales merely by measuring out that number of fluid ounces of stock solution in the omnipresent hatchery graduate calibrated in fluid ounces. Any strength of stock solution may be used although the one given above has proved most practical. In using stock solutions in the apparatus previously described, the required amount should always be added to the bottle-reservoir before the water is added. Unless made with distilled water, the stock solutions should be discarded after one month.

## IV. Inaccuracy of Available Methods for Administering Prolonged Treatments

Regardless of the accuracy with which any apparatus will deliver the disinfecting solution into the inflowing water, the entire method of prolonged treatment now employed is subject to an inherent error in that it is based upon the disinfectant-concentration in the inflowing water. It is erroneously assumed that the disinfectant-concentration in the trough or pond undergoing treatment will be the same. While the discrepancy between the two concentrations is not of serious consequence in the case of hatchery troughs or very small raceways, it becomes progressively more serious as the size of the equipment to be treated is increased. The difference between the disinfectant-concentration of the inflowing water and that in the pond is caused by the residual water which must be left in the pond at the time the treatment is started. If the pond could be drained completely before treatment is started, this discrepancy would not occur, but this cannot be done in large ponds without injury to the fish.

To assume a hypothetical example: A circular pool is to be treated which is 20 feet in diameter, normally carries 12 inches of water at the periphery, 24 inches of water at the center, and is supplied with

30 gallons of water per minute. Immediately prior to treatment, this pool is drained to a minimum level consistent with the well being of the fish and which may be represented as a zero depth at the periphery and a 12-inch depth at the center. Treatment is started on the basis that the inflowing water will be a 1 to 200,000 solution of the disinfectant. While the inflowing water does represent a 1 to 200,000 dilution during the entire one-hour period of treatment, this is not true of the water in the pond. This pool, filled to the dimensions stated in the hypothesis, contains 3,141.5 gallons of water, of which 785.3 gallons are the residual water which was left in the pool when the treatment was started. Assuming that perfect replacement of the water in this pool occurs during the period of treatment (which is obviously impossible because of the mixing of the inflowing water with the residual water), the disinfectant-concentration in the pool could not possibly reach a 1 to 200,000 strength until the pond had filled and the entire 785.3 gallons of residual water had been pushed out the drain. This process (at 30 gallons per minute inflow) would require approximately 105 minutes which is almost twice the period of the treatment. If, as is sometimes done, a shorter standpipe is placed in the drain so that the water level will be maintained during treatment at the reduced height at which treatment was started, even under the conditions of perfect replacement, twenty-six minutes of the one-hour period of treatment would be utilized in replacing the residual water so that the disinfectant-concentration may reach the desired 1 to 200,000 solution. As perfect replacement does not occur in any type of pond, what actually happens in a pond undergoing prolonged treatment supposedly at a definite concentration over a definite period of time, is a gradual increase in the disinfectant-cencentration at an unknown rate. A peak of unknown concentration is eventually reached, and is followed by a rapid decrease in disinfectant-concentration when the pond is drained at the conclusion of the one-hour period—again the rate of decreasing concentration being unknown. In other words, this prolonged treatment did not consist of a definite period of exposure to a definite disinfectant-concentration as was planned, but instead, of a series of fluctuating unknown disinfectant-concentrations which at no time during the entire period of treatment actually reached the desired concentration.

The discrepancy between the disinfectant-concentration in the inflowing water and that in the pond becomes less serious as the amount of residual water in the pond at the start of the treatment approaches zero or as the ratio between the volume of inflow and the capacity of the pond approaches unity. The discrepancy in disinfectant-concentrations may be disregarded in troughs or small shallow raceways which fill rapidly and which may be drained practically to dryness at the start of the treatment. Prolonged treatment by applying the disinfectant to the inflowing water, therefore,

is quite adaptable to such types of fish cultural equipment but it is highly questionable if this method is suited to the larger types of equipment such as circular pools and big raceways.

To circumvent the inherent limitations of this method for prolonged treatments of pools and raceways, the Bureau's West Coast Laboratory, in cooperation with Mr. Fred J. Foster, Regional Director for the Division of Fish Culture, and various members of his staff[2], has been experimenting with the use of a closed circulation of disinfecting solution for treating fish in ponds (Figure 2). In this method of prolonged treatment, the volume of water contained in a pond at any given height is calculated (a very simple procedure by using standard mensuration formulae) and the necessary weight of disinfectant dissolved in some convenient receptacles. The water in the pond is then aerated by recirculation through the use of a small centrifugal pump (powered by an electric motor or a stationary gas engine if electric power is not available) to return the water from the normal point of outflow back to the point of inflow. The inflowing water is then stopped and the dissolved disinfectant spread as uniformly as possible over the entire pond and thoroughly mixed with a long handled brush. In this way, the desired disinfectant-concentration is reached in the pond in a minimum period of time and may be maintained uniformly constant for as long a period of time as may be desired.

This method for prolonged dipping by recirculation is still in the experimental stage and its potentialities and limitations are being studied. However great or small these may eventually prove to be, nevertheless, this method offers all of the advantages to be gained by mixing the disinfectant with the inflowing water without so many of the disadvantages attendant upon the other methods. The recirculation method accomplishes in fact the theoretical results that have been claimed for the treatment of inflowing water. This method does so with more accuracy, convenience, and economy than any other when applied to the larger types of fish cultural equipment which, in the final analysis, are the types of equipment in which the problems of combating diseases are most acute.

## Summary

1. The chief limitations of the prevention and control of diseases among hatchery fish by present means of prolonged treatment are: (a) the unknown toxicity and efficacy of disinfectants under varying factors of concentration, duration of exposure, temperature, and the chemical and organic content of the water; (b) the fragility of the apparatus now generally employed; (c) the relatively complex calculations involved in applying prolonged treatments with present

[2]Particularly Messrs. Joe Kemmerich, Elmer Wood, Kenneth King, and Einar Evanson.

apparatus; and (d) the inherent inaccuracy of the present methods of prolonged treatment. This paper describes means which have been developed by the U. S. Bureau of Fisheries West Coast Pathology Laboratory for obviating these limitations.

2. The construction and operation of a simplified apparatus for administering disinfecting solutions to inflowing water to a trough for the purpose of prolonged treatments are described.

3. A method for prolonged treatment by recirculating the disinfecting solution in a closed system is described. This method is believed to be better adapted for use in ponds, circular pools, and raceways than is the usual method of treating the inflowing water.

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# FEEDING HABITS OF THE MONTANA GRAYLING (*THYMALLUS MONTANUS* MILNER) IN FORD LAKE, MICHIGAN[1]

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ABSTRACT

Owing to the probable extinction of the native Michigan grayling, especial interest attaches to progress of experimental plantings of the Montana grayling in various Michigan waters. This report concerns the feeding habits of a population of the latter species established in a small landlocked lake in northern Michigan.

Earlier reports on the feeding habits of Michigan, Montana, and European grayling are few and very general; hence, a careful study has been made of the food organisms taken by the Ford Lake specimens. Tabulation of results shows the diet to comprise a surprisingly large number of predacious invertebrates—dragonfly nymphs, backswimmers, and dytiscid beetles being particularly abundant. It is hoped that continued observations may throw light on the problem of selection *vs.* availability in feeding habits.

Fisheries investigators have long been asking themselves what factors have been responsible for the disappearance of the Michigan grayling (*Thymallus tricolor* Cope), and for the current marked annual diminution of the once abundant Montana grayling (*Thymallus montanus* Miln.) in its native waters. The grayling in each instance seem to fail under the effects of increasing human activity and of propagation of trout, which may be detrimental to grayling through competition, active predation, or both. This condition is all the more puzzling when one considers the fact that the closely related European grayling has not only survived the activities of human agencies and existence of various salmonid fishes in the same waters, but persists in such numbers as to be considered a "weed fish" by many anglers, and in consequence is subjected to stern control measures.

On May 18, and from October 18 to 20, 1937, Doctors A. S. Hazzard and R. W. Eschmeyer collected small samples of the Montana grayling population which was introduced into Ford Lake, Pigeon River State Forest (T. 32 N., R. 1 W., Sec. 8, Otsego County, Michigan) during the fall of 1936. Owing to the keen interest with which fisheries biologists have been following the fate of Montana grayling stockings of Michigan waters, the fishes collected in the above sampling series were considered deserving of special study. The present report is concerned with an analysis of the feeding habits. It is to be hoped that this and additional studies to be carried out during the progress of the Ford Lake experiment may yield facts with which to answer some of the perplexing questions and speculations brought on by the failure and probable extinction of the native Michigan grayling.

[1]Contribution from the Institute for Fisheries Research, Ann Arbor, Michigan.

Early accounts of the Michigan grayling include only sketchy observations on its feeding habits, but comments on its numbers seem almost incredible to present-day readers. Thaddeus Norris (1883), writing of a boat trip down the Au Sable River made in 1874, mentions that: "On our second day we killed and salted down—heads and tails off—a hundred and twenty pounds of fish [grayling], besides eating all we wanted." Again, on the same trip: "I took at five casts fifteen fish [grayling], averaging three-quarters of a pound each." Of the feeding habits, he simply states that: "The various orders of flies which lay their eggs in running waters, and the larvae of such flies, appear to be their only food." Parker (1889), while discussing a vain attempt to take grayling spawn, states that stomachs of several grayling taken by angling contained a large amount of vegetable material, particularly oat grains, a quantity of which had been spilled in the stream. He suggests, rather hesitantly, that vegetation might be a normal complement to the diet, adducing the supposed thyme-like odor and flavor of the graylings in support of this. Milner (1874) mentions that stomachs of grayling taken by him from the Au Sable contained Coleoptera, Neuroptera, and nymphs of various species of Odonata. Also present were leaves of the white cedar, which he believed were taken by mistake and not selected as food.

In a paper dealing with artificial propagation of the Montana grayling, Henshall (1907) wrote very briefly that the food consists of insects and their larvae.

According to Heckel and Kner (1858), the European grayling (*Thymallus thymallus*) feeds upon worms, snails, insect larvae, spawn, young fish fry, and various small minnows. Dealing with the same species, von Siebold (1863) mentioned further that such seasonally available insects as beetles, bugs, leaf-hoppers, grasshoppers, wasps and ants are taken.

Svetvidov (1931), in an account of the habits of the grayling of Lake Baikal, stated that the diet of the black grayling is formed of amphipods, caddisflies, and adult winged insects, while the white grayling feeds chiefly upon fish and amphipods.

Since a description of Ford Lake has been given by Eschmeyer (1937), it will be sufficient at this time to mention a few of its more salient characteristics. The lake is situated in the midst of rolling, sandy country grown with jack pine and aspen, and receives a relatively small amount of surface drainage. In a survey made by Mr. J. B. Schwerdt, Project Superintendent of Camp Vanderbilt, U. S. Park Service, during the summer of 1936, the surface area was determined as 10.66 acres. In a survey conducted by the Institute for Fisheries Research, the bottom in the deeper portions of the lake was found to be composed uniformly of pulpy peat. The rather extensive shoal areas, averaging 175 feet in width, were composed of sand on the north, east and south sides, separated from the peat

TABLE 1.—AMOUNTS AND DISTRIBUTION OF FOOD ORGANISMS IN MONTANA GRAYLING STOMACHS FOR MAY AND COMBINED OCTOBER COLLECTIONS

| Organism | May 18, 1937 | | | | October 18 to 20, 1937 | | | |
|---|---|---|---|---|---|---|---|---|
| | Per cent of stomachs containing organism | Average number per stomach | Total volume in cubic centimeters | Per cent by volume | Per cent of stomachs containing organism | Average number per stomach | Total volume in cubic centimeters | Per cent by volume |
| Cladocera (Water fleas) | ——— | ——— | ——— | ——— | 87.5 | ——— | 2.865 | 15.8 |
| Copepoda (Copepods) | ——— | ——— | ——— | ——— | 15.6 | ——— | trace | ——— |
| Amphipoda (Scuds) | 16.0 | 0.24 | 0.025 | 0.4 | 90.6 | 67.8 | 4.730 | 26.0 |
| Ephemeroptera (Mayfly nymphs) | 14.0 | 0.16 | 0.130 | 1.9 | 6.2 | [1]___ | 0.025 | 0.1 |
| Odonata (Dragonfly nymphs) | 30.0 | 1.68 | 1.300 | 19.6 | 43.7 | 10.4 | 4.610 | 25.3 |
| Aquatic Hemiptera (Water bugs) | 28.0 | 0.34 | 0.090 | 1.4 | 60.6 | 1.4 | 2.000 | 11.0 |
| Terrestrial Hemiptera (Land bugs) | ——— | ——— | ——— | ——— | 6.2 | 0.1 | 0.075 | 0.4 |
| Homoptera (Aphids) | ——— | ——— | ——— | ——— | 53.1 | 19.8 | 1.003 | 5.5 |
| Corrodentia (Psocids) | ——— | ——— | ——— | ——— | 25.0 | 0.8 | trace | ——— |
| Aquatic Coleoptera (Water beetles) | 60.4 | 8.60 | 0.560 | 8.5 | 43.7 | 0.8 | 0.600 | 3.3 |
| Terrestrial Coleoptera (Land beetles) | 10.0 | 0.10 | 0.050 | 0.8 | 50.0 | 1.3 | 0.375 | 2.0 |
| Trichoptera (Caddis flies) | ——— | ——— | ——— | ——— | 9.4 | 0.1 | 0.250 | 1.4 |
| Aquatic Lepidoptera (Aquatic moths) | 2.0 | 0.04 | 0.025 | 0.4 | ——— | ——— | ——— | ——— |
| Hymenoptera (Ants and wasps) | 12.0 | 0.12 | 0.115 | 1.6 | 5.0 | 1.1 | 0.100 | 0.5 |
| Aquatic Diptera (Midge larvae and pupae) | 96.0 | 44.40 | 4.340 | 65.4 | 93.7 | 28.4 | 1.540 | 8.5 |
| Terrestrial Diptera (Land flies) | 4.0 | 0.04 | trace | ——— | 28.1 | 0.4 | 0.045 | 0.2 |
| Hydracarina (Water mites) | 14.0 | 0.46 | trace | ——— | 15.6 | 0.4 | trace | ——— |
| Terrestrial Araneae (Spiders) | ——— | ——— | ——— | ——— | 6.2 | 0.1 | trace | ——— |

[1]Less than 0.1.

by a belt of marl of approximately equal width. The maximum depth was 10 meters; slope 20 to 30 degrees; Secchi disc reading 5.5 meters; pH at all levels 8.2. At the time of the survey (August 1, 1932) a thermocline was formed between the 5- and 6-meter levels. There were 9.4 p.p.m. of dissolved oxygen at the surface, 8.6 p.p.m. at the bottom.

The results of stomach analyses are recorded in the accompanying tables which give some indication of the feeding habits of the fish over a 24-hour period. They also reveal some rather unusual organism dominances. It will not be possible to state to what extent the diet is determined by selection or by necessity until further information has been gathered on the numbers and availability of food organisms actually present in the lake. An attempt will be made at a future date to determine the condition factor for the grayling, in hope of shedding additional light on the adequacy of their available food supply. The tabulations of food organisms, listed by taxonomic order, are briefly discussed as follows:

*Collection 1.* May 18, 1937 (Table 1). This sample was taken by a single haul of a 100-foot bag seine through water from 2 to 8 feet in depth, over a sparsely-weeded section of shoal at the east end of the lake. Fifty specimens were examined, ranging from 67 to 111 millimeters in standard length, average 89 millimeters, or approximately 3¼ to 5 inches in total length.

It may be seen that well over one-half of the diet was composed of aquatic Diptera. Complete tabulation of all the components of this order is not feasible; but it may be stated that forty-eight fish contained no other Diptera than larvae and pupae of midges (Chironomidae and Ceratopogonidae), while two contained larvae of the culicid phantom midge, *Chaoborus* (*Corethra*) *punctipennis.* Of greater interest is the unusually large showing made by two other orders, Odonata and Coleoptera. The former is represented by many nymphs of the zygopterous species *Enallagma carunculatum* and *E. hageni,* and by four nymphs of the anisopterous genus *Tetragoneuria.* The Coleoptera are represented by a few terrestrial dung-beetles of the family Scarabeidae, chiefly of the genus *Aphodius.* By far the more numerous, however, are minute adult dytiscid water beetles of the genus *Bidessus.* These insects seldom exceed 2 millimeters in length, but were present in numbers sufficient to account for most of the 8.5 per cent of total volume made up by aquatic Coleoptera. All the mayflies taken are nymphs of the family Baetidae. All the Amphipoda, or scuds, have been determined as *Hyalella knickerbockeri.* In passing, it is deserving of notice that among the aquatic Hemiptera taken are backswimmers of the relatively rare species *Plea striola,* one water bug, *Belostoma,* sp., and one water strider. Past work has shown that representatives of these three groups are seldom eaten by fish, possibly because of their musky odor and the fact that some are capable of inflicting painful stings.

TABLE 2. FREQUENCY OF OCCURRENCE, VOLUME AND PER CENT BY VOLUME OF FOOD ORGANISMS IN MONTANA GRAYLING STOMACHS IN OCTOBER, 1937

| Item | Cladocera (Water fleas) | Copepoda (Copepods) | Amphipoda (Scuds) | Ephemeroptera (Mayfly nymphs) | Odonata (Dragonfly nymphs) | Aquatic Hemiptera (Water bugs) | Aquatic Coleoptera (Water beetles) | Trichoptera (Caddis larvae) | Aquatic Diptera (Midge larvae & pupae) | Hydracarina (Water mites) | Corrodentia (Psocids) | Terrestrial Hemiptera (Land bugs) | Homoptera (Aphids) | Terrestrial Coleoptera (Land beetles) | Terrestrial Diptera (Land flies) | Hymenoptera (Ants and wasps) | Araneae (Spiders) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **October 18, evening** | | | | | | | | | | | | | | | | | |
| Per cent of stomachs containing organism | 90.9 | 45.5 | 90.9 | 9.1 | 45.5 | 54.5 | 27.2 | 18.2 | 100.0 | 18.2 | 45.5 | 9.1 | 72.7 | 63.6 | 45.5 | 72.7 | 0 |
| Average number of organisms per stomach | ------- | ------- | 10.2 | 0.1 | 21.6 | 1.6 | 0.3 | 0.2 | 55.4 | 0.6 | 2.3 | 0.1 | 48.6 | 2.1 | 0.8 | 1.2 | 0 |
| Total volume in cubic centimeters | 0.760 | trace | 0.180 | 0.025 | 2.850 | 0.525 | 0.050 | trace | 1.120 | trace | trace | 0.025 | 0.775 | 0.200 | 0.025 | 0.100 | 0 |
| Per cent by volume | 10.8 | ------- | 2.6 | 0.4 | 46.1 | 7.5 | 0.7 | ------- | 15.9 | ------- | ------- | 0.4 | 11.0 | 2.8 | 0.4 | 1.4 | 0 |
| **October 19, morning** | | | | | | | | | | | | | | | | | |
| Per cent of stomachs containing organism | 100.0 | 0 | 100.0 | 0 | 50.0 | 62.5 | 62.5 | 12.5 | 100.0 | 0 | 0 | 0 | 87.5 | 75.0 | 25.0 | 62.5 | 25.0 |
| Average number of organisms per stomach | ------- | 0 | 99.0 | 0 | 1.1 | 1.2 | 1.8 | 0.2 | 23.8 | 0 | 0 | 0 | 18.7 | 1.7 | 0.4 | 0.9 | 0.4 |
| Total volume in cubic centimeters | 0.225 | 0 | 2.248 | 0 | 0.240 | 0.825 | 0.400 | 0.250 | 0.345 | 0 | 0 | 0 | 0.197 | 0.125 | 0.020 | trace | 0.125 |
| Per cent by volume | 4.5 | 0 | 45.0 | 0 | 4.8 | 16.5 | 8.0 | 5.0 | 6.9 | 0 | 0 | 0 | 3.9 | 2.5 | 0.4 | ------- | 2.5 |
| **October 19, 10:15 a.m.-7:00 p.m.** | | | | | | | | | | | | | | | | | |
| Per cent of stomachs containing organism | 71.4 | 0 | 85.7 | 0 | 28.5 | 71.4 | 71.4 | 0 | 85.7 | 14.2 | 0 | 0 | 28.5 | 28.5 | 14.2 | 42.8 | 0 |
| Average number of organisms per stomach | ------- | 0 | 154.8 | 0 | 1.6 | 1.4 | 1.0 | 0 | 9.6 | 0.1 | 0 | 0 | 3.3 | 0.6 | 0.1 | 0.4 | 0 |
| Total volume in cubic centimeters | 1.750 | 0 | 1.500 | 0 | 0.125 | 0.425 | 0.150 | 0 | 0.100 | trace | 0 | 0 | 0.025 | 0.050 | trace | trace | 0 |
| Per cent by volume | 42.4 | 0 | 36.4 | 0 | 3.0 | 10.3 | 3.6 | 0 | 2.4 | ------- | 0 | 0 | 0.60 | 1.2 | ------- | ------- | 0 |
| **Oct. 19. 7:30 a.m.-Oct. 20, 1:00 p.m.** | | | | | | | | | | | | | | | | | |
| Per cent of stomachs containing organism | 83.3 | 0 | 83.3 | 0 | 66.6 | 66.6 | 16.6 | 0 | 83.3 | 83.3 | 0 | 0 | 0 | 16.6 | 16.6 | 0 | 0 |
| Average number of organisms per stomach | ------- | 0 | 53.8 | 0 | 12.7 | 1.0 | 0.2 | 0 | 5.3 | 1.0 | 0 | 0 | 0 | 0.3 | 0.2 | 0 | 0 |
| Total volume in cubic centimeters | 0.085 | 0 | 0.755 | 0 | 0.710 | 0.300 | 0.050 | 0 | trace | trace | 0 | 0 | 0 | trace | trace | 0 | 0 |
| Per cent by volume | 4.5 | 0 | 39.7 | 0 | 37.4 | 15.8 | 2.6 | 0 | ------- | ------- | 0 | 0 | 0 | ------- | ------- | 0 | 0 |

*Collection 2*. October 18, 1937, evening (Table 2). Sample, collected by seining in shoal water at the east end of the lake, consists of eleven specimens ranging in standard length from 148 to 176 millimeters, average 165 millimeters, approximately 6¾ to 8 inches total length.

Of particular interest in this sample are: (a) the large number of Odonata nymphs (belonging, as in each instance following, to the same species of *Enallagma* recorded for Collection 1), these occurring in sufficient quantity to compose almost one-half of the total amount of food taken; (b) the appreciable amount (16 per cent) of terrestrial insects, indicating readiness of grayling of this size to feed on surface food when it is available; and (c) the appearance of plankton, in the form of Cladocera, or water fleas. The large volume of *Enallagma* nymphs is the more striking in view of the fact that at this time of year all such nymphs are in early stages, each nymph having but a small fraction of the bulk attained by late spring. One stomach contained eighty-five nymphs. Powerfully stinging backswimmers, *Notonecta insulata,* appear in surprising quantities.

*Collection 3*. October 19, 1937, morning (Table 2). The sample, collected by seining in shoal water at the east end of the lake, consists of eight specimens ranging in standard length from 147 to 179 millimeters, average 163 millimeters, approximately 6⅞ to 8½ inches total length.

In this series scuds proved to be the most important food item. It may be pointed out that since it is probable that the stomachs in this sample were filled with organisms taken during night feeding, the scanty amount of terrestrial organisms found is what would be expected. This is one of two collections in which two caddis larvae appear. Here again examples of *Notonecta insulata* occur in an abundance which accounts for most of the volume ascribed to aquatic Hemiptera in the table. Larvae of the phantom midge, *Chaoborus* (*Corethra*) *punctipennis,* occur in significant numbers for the first time, being responsible for all the measurable volume of aquatic Diptera, although larvae and pupae of the Chironomidae are present in small numbers. One stomach contained a statoblast of the polyzoan, *Cristatella mucedo.*

*Collection 4*. October 19, 1937, 10:15 a.m. to 7:00 p.m. (Table 2). Sample, collected by means of gill-nets, consists of seven individuals ranging in standard length from 151 to 183 millimeters, average 163 millimeters, approximately 7⅛ to 8½ inches total length.

This collection is of interest for the large amount of plankton and the very small amount of midge larvae and pupae taken. The aquatic Hemiptera is again an important group due to the number of backswimmers consumed. The very low volume of terrestrial organisms encountered indicates that little surface feeding had been carried on immediately prior to capture.

*Collection 5*. October 19, 7:30 p.m. to October 20, 1:00 p.m., 1937

(Table 2). This sample, also collected by means of gill-nets, consists of six specimens ranging in standard length from 148 to 165 millimeters, average 159 millimeters, approximately 7 to 7⅝ inches total length.

As in Collection 2, *Enallagma* nymphs exceed all other groups in total volume. Aside from the fact that Odonata and Cladocera occupy transposed ranks, this collection conforms rather closely with the pattern recorded for the other gill-net lift, Collection 4. In the present instance, only one phantom midge larva (*Chaoborus*) was encountered, the low total percentage of aquatic Diptera being made up by a small number of larvae and pupae of two subfamilies of true midges, Chironominae and Tanypodinae.

Table 1 shows results obtained by combining findings for the four October collections. Calculated on this basis, it will be seen that scuds and odonate nymphs share the position of first importance with a difference of only 0.7 per cent. A few points worthy of attention are the low percentage of total diet composed of midge larvae and pupae when considered from the standpoint of all the October samples; the relatively high percentage of aquatic Hemiptera; and the very small amount of mayfly nymphs utilized. Three groups of organisms were taken in quantities too small to affect the percentages. These are Copepoda, members of the plankton; Hydracarina, free swimming water mites; and Corrodentia, represented by the Psocidae, a family of terrestrial insects allied to the book lice.

*General Considerations:* Because no previous work dealing with the natural feeding habits of lake-inhabiting Montana grayling has been published, it is impossible to state whether or not the Ford Lake specimens were subsisting on a normal diet. Thus, the rather surprising low percentage of midge larvae and pupae taken in the October collections (this group having far outstripped all others in the May sample) may be due to seasonal decrease in the midge population, or to a change in diet preference connected with size increase on the part of the fish.

The most surprising finding is the very large quantity of predacious forms consumed.[2] Nymphs of the Odonata are predatory in habits from hatching to maturity. The nymphs of *Enallagma,* which make up the bulk of the Odonata taken in both the May and October samples, feed upon animal plankton when young, but soon change to a diet composed chiefly of smaller insect larvae. The aquatic Hemiptera are represented almost exclusively by *Notonecta insulata,* one

[2]Since the above study was completed, a single winter-caught specimen from Ford Lake has been examined and found to agree with the others in containing a large amount of predacious insect larvae. The specimen, having a standard length of 196 millimeters, a total length of 8⅞ inches, and a weight of 100 grams, was collected through the ice on February 27, 1938, by Dr. A. S. Hazzard, using hook and line with a stonefly nymph for bait. The stomach was found to contain ten scuds (Amphipoda), remains of six dragonfly nymphs (*Anax junius*), and a single chironomid midge larva. The dragonfly nymphs accounted for 98.6 per cent, the scuds 1.4 per cent, and the midge larva a trace, of the total volume.

of the largest backswimmers in the state, known for its voracity which extends to small fish as well as to a variety of aquatic insects and small crustaceans. The aquatic Coleoptera are best represented by the Dytiscidae, a group whose feeding habits are predacious in both larval and adult stages.

Further study of food consumed and of food organisms present in the lake are demanded to demonstrate whether such a diet is determined by necessity or preference. The need for such studies is further emphasized by comparing the tabulations for May and the combined October data in Table 1. While Odonata nymphs hold second place in the percentage columns in both instances, wide discrepancies appear in the positions of various other groups, especially the aquatic Diptera and the scuds. No sure explanation can now be offered for the absence, in the May sample, of plankton which is well represented (by the Cladocera) in the October collections. Examinations of seasonal plankton abundance, as well as that of larger food organisms, should be made to afford added information on the important question of selection *vs.* availability in determining feeding habits.

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# RESULTS FROM EXPERIMENTAL PLANTINGS OF LEGAL-SIZED BROOK TROUT (*SALVELINUS FONTINALIS*) AND RAINBOW TROUT (*SALMO IRIDEUS*)[1]

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## ABSTRACT

An intensive creel census in conjunction with monthly releases, during the fishing season, of legal-sized trout, approximately one-half of which were jaw-tagged or fin-clipped, furnished data for the evaluation of such plantings in the Pine River, Michigan. Nearly 8,500 hours of fishing yielded 3,171 brook trout and 3,333 rainbow trout for an average catch of 0.77 fish per hour. Forty-six per cent of the brook trout reported and 21 per cent of the rainbows were from these plantings. Incomplete records of the marked fish showed recovery of 19.8 per cent of 7,513 brook trout and 17.5 per cent of 4,007 rainbows planted. The catch per hour by weekly periods ranged from 0.32 to 1.35. The average catch per hour for the Pine was considerably higher than for the other streams that were covered by a similar census but not planted with large fish. The plantings influenced the catch for a period of from two to three weeks. Apparently few of these fish survive to the next season. Movement of planted fish was mainly upstream regardless of the method of planting. Within two weeks the fish which remained were uniformly distributed over the stream. "Spot" planting resulted in a larger percentage caught than did scattering by boat, but increased "meat fishing." Every planting during the open season caused a decided rise in the catch of wild fish of the same species. It is concluded that although planting legal fish during the season temporarily and artificially increases the catch, it may deplete a stream of wild adults. This depletion will affect natural production and may result in poorer fishing in succeeding years. A program for planting legal-sized trout appears justified only in heavily fished waters incapable of supporting a permanent trout population during the summer or where no results from natural reproduction are possible, or where an overpopulation of stunted trout exists.

## INTRODUCTION

In recent years a number of states, particularly those with very limited trout waters subjected to heavy fishing pressure, have been stocking many adult trout. Fisheries administrators in these states seem to feel that this procedure is the only way to satisfy the anglers at least partially. In a recent address delivered before the New York State Wildlife Conference, Senator Walcott (1938) described the present program[2] of planting large fish in Connecticut with the statement that the "program works in a *small* state where you can keep it under control and face the facts by deliberately treating it as a manufacturing proposition."

Michigan has been planting a small percentage of yearling trout

[1]Contribution from the Michigan Institute for Fisheries Research.

[2]Connecticut releases a large number of legal-sized trout but also stocks spring-fed tributaries with fry and the less heavily fished larger streams with fingerlings.

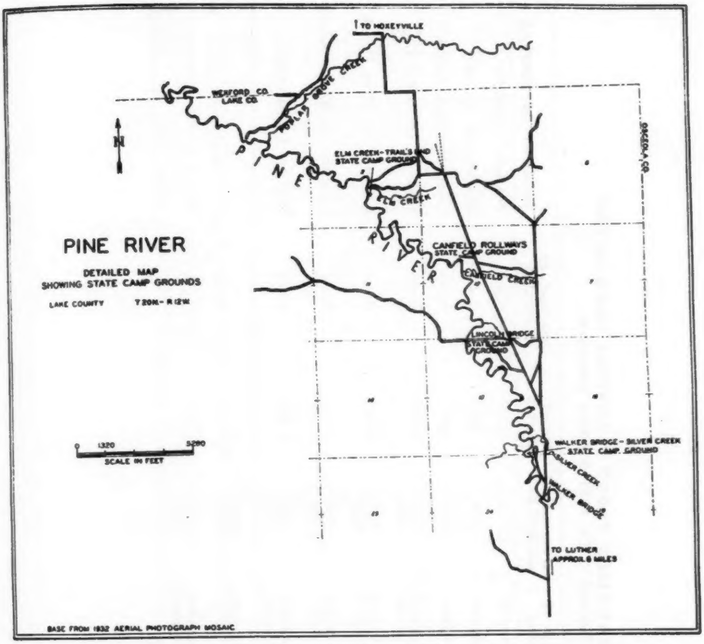


Figure 1.—Section of Pine River showing location of state camp grounds.

in certain waters but recently there have been increased demands for larger fish in different parts of the state. Before embarking on a program which would entail new pond development and heavy additional expense, our Commission decided that experiments should be performed by its Institute for Fisheries Research to determine the results from such plantings.

A portion of the Pine River, a branch of the Big Manistee, was chosen as the test stream where most of the experiments were to be conducted. In the section under observation the stream has an average width of about 50 feet. The current is rapid to sluggish and the bottom is dominantly sand and gravel with rather frequent clay outcrops. Two fair-sized tributaries and a number of springs feed this portion of the river. The land along this portion of the stream for a distance of about 12 miles below the Walker Bridge is owned or leased by the Department of Conservation. The Department has developed five public camp sites in this section as indicated in Figure 1.

In conducting the census, C.C.C. enrollees were stationed at each

**TABLE 1. DETAILS OF LEGAL-SIZED TROUT PLANTINGS MADE IN THE PINE RIVER DURING THE 1937 TROUT SEASON**

| Date planted | Species | Average total length (inches)[1] | Method of marking | Number of marked fish | Total planted | Method of planting | Location[2] of planting |
|---|---|---|---|---|---|---|---|
| May 18, 19 | Brook | 9.0 | Jaw-tagged | 1,000 | 3,000 | Spot | Walker, Canfield |
| June 15 | Brook | 8.8 | Jaw-tagged | 959 | 959 | Boat | Walker to Lincoln |
| June 15 | Rainbow | 10.1 | Jaw-tagged | 1,007 | 2,007 | Spot | Canfield, Elm Creek |
| July 13 | Brook | 8.8 | Jaw-tagged<br>Fin-clipped | 504<br>500 | 2,004 | Boat | Walker to Lincoln |
| July 13 | Rainbow | 9.8 | Jaw-tagged<br>Fin-clipped | 250<br>250 | 1,000 | Boat | Lincoln to Elm Creek |
| August 10 | Brook | 8.6 | Jaw-tagged<br>Fin-clipped | 500<br>500 | 1,550 | Boat | Lincoln to Elm Creek |
| August 10 | Rainbow | 10.6 | Jaw-tagged<br>Fin-clipped | 250<br>250 | 1,000 | Boat | Walker to Lincoln |
| Total | Brook | ------ | Jaw-tagged<br>Fin-clipped | 2,963<br>1,000 | 7,513 | ------------ | ---------------------- |
| Total | Rainbow | ------ | Jaw-tagged<br>Fin-clipped | 1,507<br>500 | 4,007 | ------------ | ---------------------- |

[1]Based on average length of tagged fish.

[2]See map, Figure 1, for locations.

TABLE 2. COMPOSITION OF CATCH AS RECORDED IN PINE RIVER CENSUS BY WEEKLY PERIODS DURING 1937 FISHING SEASON

| Weekly period number | Week | Number of fishermen | Hours of fishing | Total[2] number of marked trout[3] | | Calculated total number of brook trout | | Calculated total number of rainbow trout | | Catch per hour of brook trout | | Catch per hour of rainbow trout | | Catch per hour of all trout |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Brook | Rainbow | Wild | Hatchery | Wild | Hatchery | Wild | Hatchery | Wild | Hatchery | |
| 1 | Apr. 24-30 | 200 | 864.75 | ...... | ...... | 143 | ...... | 137 | ...... | 0.16 | ...... | 0.16 | ...... | 0.32 |
| 2 | May 1-7 | 170 | 688.25 | ...... | ...... | 136 | ...... | 236 | ...... | 0.20 | ...... | 0.34 | ...... | 0.54 |
| 3 | May 8-14 | 146 | 758.25 | ...... | ...... | 100 | ...... | 250 | ...... | 0.13 | ...... | 0.33 | ...... | 0.46 |
| 4 | May 15-21[1] | 192 | 758.75 | 241 | ...... | 65 | 723 | 212 | ...... | 0.09 | 0.95 | 0.28 | ...... | 1.32 |
| 5 | May 22-28 | 200 | 840.00 | 154 | ...... | 293 | 462 | 184 | ...... | 0.35 | 0.55 | 0.22 | ...... | 1.12 |
| 6 | May 29-June 4 | 153 | 613.50 | 5 | ...... | 145 | 15 | 136 | ...... | 0.24 | 0.02 | 0.22 | ...... | 0.48 |
| 7 | June 5-11 | 141 | 646.50 | 1 | ...... | 90 | 3 | 214 | ...... | 0.13 | 0.01 | 0.33 | ...... | 0.47 |
| 8 | June 12-18[1] | 92 | 345.25 | 15 | 68 | 102 | 30 | 149 | 136 | 0.30 | 0.09 | 0.43 | 0.39 | 1.21 |
| 9 | June 19-25 | 70 | 261.50 | 11 | 35 | 12 | 22 | 67 | 70 | 0.04 | 0.08 | 0.26 | 0.27 | 0.65 |
| 10 | June 26-July 2 | 57 | 278.50 | ...... | 33 | 18 | ...... | 62 | 66 | 0.06 | 0.00 | 0.22 | 0.24 | 0.52 |
| 11 | July 3-9 | 90 | 344.25 | 4 | 26 | 35 | 8 | 115 | 52 | 0.10 | 0.03 | 0.33 | 0.15 | 0.61 |
| 12 | July 10-16[1] | 30 | 150.75 | $20_{9}$ | $20_{1}$ | 69 | 40 | 54 | 40 | 0.45 | 0.27 | 0.36 | 0.27 | 1.35 |
| 13 | July 17-23 | 69 | 279.50 | $22_{11}$ | $43_{10}$ | 82 | 44 | 138 | 86 | 0.29 | 0.16 | 0.49 | 0.31 | 1.25 |
| 14 | July 24-30 | 56 | 207.25 | $3_{1}$ | 7 | 63 | 6 | 71 | 14 | 0.30 | 0.03 | 0.34 | 0.07 | 0.74 |
| 15 | July 31-August 6 | 53 | 232.50 | 1 | 21 | 49 | 2 | 105 | 42 | 0.21 | 0.01 | 0.45 | 0.18 | 0.85 |
| 16 | August 7-13[1] | 68 | 222.00 | 17 | $43_{15}$ | 20 | 26 | 128 | 86 | 0.09 | 0.12 | 0.57 | 0.39 | 1.17 |
| 17 | August 14-20 | 89 | 369.00 | $55_{26}$ | $40_{4}$ | 133 | 85 | 143 | 80 | 0.36 | 0.23 | 0.39 | 0.22 | 1.20 |
| 18 | August 21-27 | 54 | 232.00 | $14_{1}$ | 4 | 81 | 22 | 107 | 8 | 0.35 | 0.10 | 0.46 | 0.03 | 0.94 |
| 19 | August 28-September 6 | 80 | 367.00 | ...... | 3 | 47 | ...... | 139 | 6 | 0.13 | 0.00 | 0.38 | 0.01 | 0.52 |
| Total number or aver. catch per hour | | 2,010 | 8,459.50 | $563_{48}$ | $343_{30}$ | 1,683 | 1,488 | 2,647 | 686 | 0.20 | 0.18 | 0.31 | 0.08 | [4]0.77 |

[1]Weeks of planting of hatchery fish (see Table 1).

[2]To the listed total there should be added: 8 marked trout, no data; 6 fin-clipped rainbow, no data; 2 tagged rainbow, no data.

[3]Subscript figures indicate number of fin-clipped fish included in total number of marked fish recovered.

[4]Simple average of all fishing; not by weekly periods.

camp ground (the usual points of access to the river) from 8 a.m. to 8 p.m., Sundays and holidays included, during the entire fishing season. Records were taken on regulation creel census forms as described by Eschmeyer (1935) and were submitted to the Institute for tabulation and analysis.

Beginning May 18, 1937, monthly plantings, each consisting of 3,000 trout of legal size (7 inches or over), were made in that part of the stream covered by the census. The usual composition of the releases was 2,000 brook trout and 1,000 rainbow trout (Table 1). Approximately one-half of each planting was jaw-tagged according to the method described by Shetter (1936) or marked by removal of the dorsal and adipose fins.

Two methods were employed in planting the fish. The first lot of each species was "spot planted," that is, a thousand or so trout were distributed over not more than one-quarter of a mile of stream from near the road. This is the usual method of planting trout in most states at the present time. Later releases were made by the use of a planting boat, equipped with a central well, from which the trout were liberated, a few in each pool, as the crew moved downstream.

Excellent publicity was given the experiment by the newspapers. Illustrated posters explaining the purpose of the work and requesting cooperation in reporting catches were placed at all camp grounds and at road crossings above and below the section. Many voluntary reports were received from fishermen who had been missed by the census-takers or who had caught tagged trout outside of the patrolled portion.

**TABLE 3. CALCULATED NUMBER OF HATCHERY TROUT CAUGHT FROM EACH PLANTING IN SUCCESSIVE WEEKS**

(Asterisks denote weeks in which plantings were made; for dates see Table 2.)

| Weekly period number | Number of Fish Caught from Plantings | | | | | | |
|---|---|---|---|---|---|---|---|
| | May 18, 19 3,000 brook | June 15 959 brook | June 15 2,007 rainbow | July 13 2,004 brook | July 13 1,000 rainbow | Aug. 10 1,550 brook | Aug. 10 1,000 rainbow |
| 4* | 723 | ---- | ---- | ---- | ---- | ---- | ---- |
| 5 | 462 | ---- | ---- | ---- | ---- | ---- | ---- |
| 6 | 15 | ---- | ---- | ---- | ---- | ---- | ---- |
| 7 | 3 | ---- | ---- | ---- | ---- | ---- | ---- |
| 8* | 4 | 26 | 136 | ---- | ---- | ---- | ---- |
| 9 | ---- | 22 | 70 | ---- | ---- | ---- | ---- |
| 10 | ---- | ---- | 66 | ---- | ---- | ---- | ---- |
| 11 | ---- | 8 | 52 | ---- | ---- | ---- | ---- |
| 12* | ---- | ---- | 20 | 40 | 20 | ---- | ---- |
| 13 | ---- | 2 | 50 | 42 | 36 | ---- | ---- |
| 14 | ---- | ---- | 8 | 6 | 6 | ---- | ---- |
| 15 | ---- | ---- | 22 | 2 | 20 | ---- | ---- |
| 16* | ---- | ---- | 8 | ---- | 20 | 26 | 58 |
| 17 | ---- | ---- | 10 | 4 | ---- | 81 | 70 |
| 18 | ---- | ---- | 4 | 4 | ---- | 18 | 4 |
| 19 | ---- | ---- | 2 | ---- | ---- | ---- | 4 |
| Totals | 1,207 | 58 | 448 | 98 | 102 | 125 | 136 |
| Per cent of plant | 40.2 | 6.0 | 22.3 | 4.9 | 10.2 | 8.1 | 13.6 |

## Angling Results in Relation to Plantings of Hatchery Fish

Tabulations of the fishing records have been made by weekly periods (Tables 2 and 3) except for the last period of the season (August 28-September 6). Nearly 8,500 hours of fishing were recorded during which 6,504 legal trout were caught—an average of 0.77 fish per hour. The total reported catch was made up of 3,171 brook trout and 3,333 rainbow trout. Ninety-five brown trout were reported but as their identity was questionable they were not included in the calculations.

The record of trout caught in the census area is not complete since a few fishermen left the stream before the arrival of the patrol, and others fished too late in the evening to be interviewed. The amount of training and supervision given the enrollees was not sufficient to ensure altogether complete and satisfactory data. However, it is believed that an adequate statistical sample was obtained of the season's fishing on the Pine River.

*Percentage of planted trout caught.* The percentage of captures of marked brook trout reported from plantings (Table 3) varied from 4.9 to 40.2 with a weighted average of 19.8; the percentage from rainbow trout plantings varied from 10.2 to 22.3 with a weighted average of 17.5. The percentage capture of all fish stocked recorded by the census was 18.9. These returns are lower than those reported by Cobb (1933) and Hoover (1937) but are higher on the average than those found by Nesbit and Kitson (1937). Since it is known that several marked trout were captured outside the census area and were not reported, the numbers given above should be considered as minimal. However, it is also known that there is some mortality following planting of trout of this size. A total of seventeen dead trout was picked up on two occasions following plantings. Of these, seven were tagged, three fin-clipped, and seven unmarked. Since the unmarked fish were of the same size range as the marked fish and the loss occurred at about the same time and in approximately the proportions that existed in the plantings it can be assumed that marking was not responsible for the loss. These fish were examined by Lowell A. Woodbury, who reported death as due to disease or injuries probably received in transportation.

*Effect upon the catch.* The catch per unit of fishing effort (in this paper the average number of legal trout taken per fisherman-hour) is considered by fisheries biologists as the proper index to yield. The catch per hour for the Pine River is given by weekly periods in Table 2 and shown graphically in Figures 2 and 3. These figures should be compared with Figures 4 and 5 in which are shown the catch per hour for two other Michigan streams covered by similar censuses during 1937. A marked fluctuation in the catch per hour is evident in Figures 2 to 5, ranging from 0.2 to 0.8 fish per hour

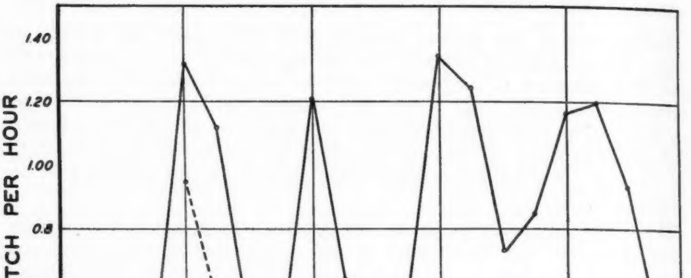


Figure 2.—Catch per hour of brook trout on the Pine River during the 1937 fishing season.

in the North Branch of the Au Sable River, from 0.32 to 1.35 for the Pine, and from 0.11 to 1.01 fish per hour in the Pigeon River.

The effects of planting "keeper" trout are readily observed in the charts for the Pine and the Pigeon rivers. These plantings are responsible for the tremendous peaks in the curves and increased the average catch per hour for the season as a whole. The average catches per hour (for the season) were as follows: for the North Branch of the Au Sable, 0.47; for the Pigeon River, 0.46; for the Pine River, 0.77. There is no question but that the plantings of legal-sized trout accounted for larger catches in the Pine River.

*How long do "keeper" plantings influence the fishing?* Regardless of the method used in planting, the liberation of such large numbers of trout does not markedly affect the fishing for longer than two or three weeks (Table 3 and Figures 2, 3 and 4). Apparently by that time the trout have disappeared from the section stocked and few if any appear in the catch thereafter. These results are in general agreement with those of Cobb (1933) except that in

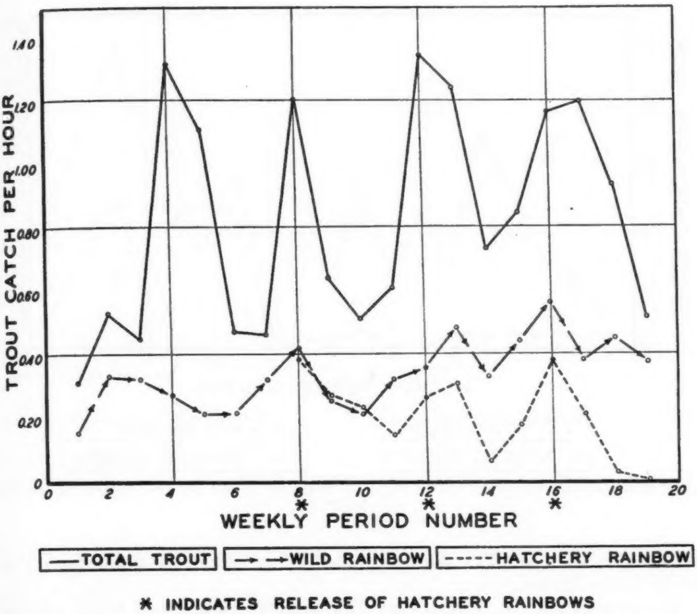


Figure 3.—Catch per hour of rainbow trout on the Pine River during the 1937 fishing season.

two plantings he found that the greatest numbers of trout were taken twenty-three and thirty-six days respectively after release. However, since Cobb did not consider the fishing intensity during the period, it is possible his figures for different plantings are not comparable.

Hoover (1937) reported that in one New Hampshire stream fishing declined rapidly during the first month of the open season (May) and "might be described as poor by the end of May at which time only 15 per cent of the 4,000 previously stocked fish had been removed." On the basis of marking experiments, he estimated that of a planting of 2,000 legal-sized brook trout made in June, 70 per cent were removed within three weeks after planting.

It seems evident that in order to keep fishing at a high level in the section of the Pine River under investigation, it would be necessary to plant 3,000 legal trout each two weeks during the open season assuming that the angling pressure remained constant. The

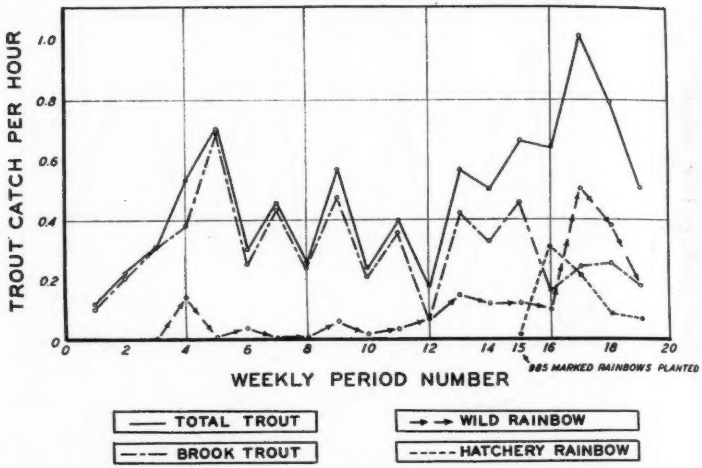


Figure 4.—Catch per hour of brook and rainbow trout on the Pigeon River for 1937.

possibility that smaller plantings would produce as good fishing is being investigated.

To date (June 16, 1938) very few reports of marked trout planted during the 1937 fishing season have been received in the census that is being conducted this year by trained departmental employees. This result is in agreement with reports by Cobb (1933), Nesbit and Kitson (1937), Walcott (1938) and Hewitt (1938), all of whom emphasized the fact that legal-sized trout do not "winter over" successfully.

*Migration of planted fish.* An analysis of the movements of marked fish demonstrates that the large majority of the recoveries of the large-sized fish was made at or relatively near (within 1 to 3 miles) the location of planting and usually within two weeks after release. In general, after two weeks, trout planted at any particular point appeared to be rather uniformly distributed over the census section but in considerably diminished numbers. A few individuals were recovered between 15 and 20 miles from the point of stocking.

"Spot-planted" brook trout moved both up and downstream within the first week's stocking, but even greater movement occurred during the second week. The majority moved upstream. Brook trout planted by boat were reported taken in or above the section in which they were distributed. The one "spot planting" of rainbows showed a dominant upstream migration which reached a peak during the third week after release. Rainbow trout distributed by boat

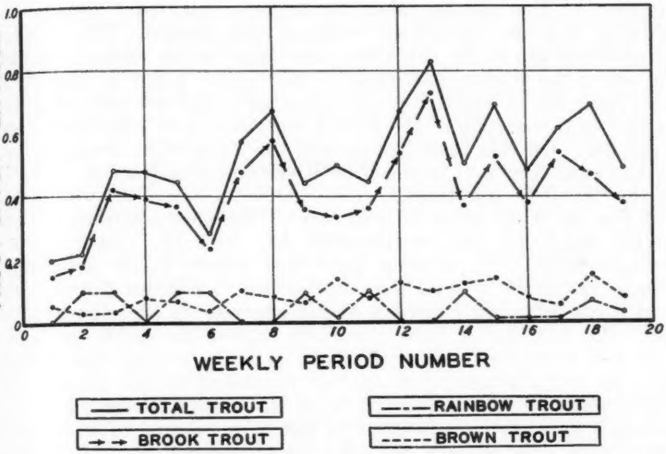


Figure 5.—Catch per hour of all trout on the North Branch of the Au Sable River for 1937.

also showed a dominant upstream movement. Greater movement of trout occurred following "spot plantings" than when the fish were distributed a few in each pool from the planting boat.

*Comparison of planting methods.* In addition to the effect upon movements after planting, significant differences in the catch resulted from the two methods. As shown by Table 3, "spot planting" yielded the largest catch from a given number of stocked fish both in brook trout and rainbow trout. In neither fish did the more expensive and difficult method of planting by boat result in a more prolonged improvement in the fishing. In fact, the single "spot planting" of rainbow trout influenced the catch for several weeks longer than did planting from a boat.

The main objection to "spot planting" of large trout is that, no matter how secretly done, it leads to "meat fishing" and highly undesirable concentrations of fishermen. In either method trout are caught out rapidly and no particular skill or persistence is required to take the limit in a short time.

*Percentage of planted and "wild"[3] fish in the catch.* The relative contribution to the catch by planted "keepers"[4] and by wild fish is of greatest significance in this investigation. Fortunately a complete record of the fish yield is not required for such a calculation. In the Pine River the planted brook trout made up 46.9 per cent of the

[3]This term will be used for fish resulting from natural spawning or previous fingerling plantings.
[4]Any trout of legal size.

number of this species taken by anglers; planted "keepers" constituted 20.6 per cent of the rainbow trout caught. The abundance of hatchery fish in the catch was very large in the weeks immediately following the plants, particularly the "spot" plant of May 18 and 19 (Table 2). Considering the entire take, 33.9 per cent of all trout caught in this section of the Pine River came from plantings of legal-sized fish. On this basis Nature and the "fingerling program" seem to be doing very well in the Pine River and at a fraction of the cost of the "keeper" plantings.

*Effect upon the catch of wild trout.* The most startling and unexpected result of this investigation has been the establishment of definite proof that *planting legal-sized hatchery fish markedly increases the catch of wild fish.* Reference to Figures 2 and 3 shows that every planting caused a significant rise in the curve for wild fish. All but one of these plantings caused the catch per hour of wild fish to exceed even that of the recently stocked fish. The reality of this relationship is further confirmed by the results of the single planting of rainbow trout in the Pigeon River (Figure 4), although here the rises in catch of hatchery fish and of wild rainbow trout were delayed one and two weeks respectively. It is of interest that only the wild trout of the species planted were affected. This fact suggests that competition may be keener between individuals of the same species than between the different species of trout.

It is entirely possible and it seems reasonable to believe that planting large numbers of big trout in a stream may increase competition for food and shelter to the point that wild fish are forced to forage more extensively and are caught more rapidly than normal. After all, the supporting capacity as well as the productive capacity of any body of water has definite limitations and unless more "homes" and food can be supplied, a stream cannot support more than a given number of fish. Surber (1937) has shown that doubling the usual plant of fingerling rainbow trout (which he found reached legal size next season) did not result in an increase in the catch the following year.

## Conclusions

These findings leave considerable room for speculation but one conclusion appears to be justified, namely, that the consistent planting of a stream with legal-sized trout during the fishing season will eventually lower the number of adult trout of breeding size to a point where the contribution to the catch from natural spawning is seriously impaired. Furthermore, this forced drain on the stock of larger trout in a stream means poorer fishing during the following seasons, especially since legal-sized trout planted during one season do not "winter over" with much success. If carried to excess the result would be a stream practically barren of trout except for those planted just prior to and through the season.

As Senator Walcott (1938) has said, planting large numbers of legal-sized trout may be the only solution for a small state with limited mileage of stream, much of which may become too warm for trout in mid-summer and in which suitable breeding grounds or breeding stock are lacking. Planting legal-sized trout may also be justified in the smaller streams of southern Michigan where the demands of fishermen are heavy and the habitat for trout is extremely limited, *provided the group benefited is willing to pay what it costs* to manufacture this substitute for the kind of fishing still available in our northern streams. It would be a financial impossibility to supply such artificial trout fishing to some 300,000 anglers in the 15,000 miles of trout streams in Michigan. Fall planting of large trout in pot hole lakes as described by Eschmeyer (1938) may, on the other hand, prove to be good management inasmuch as the fish appear to survive over winter in such waters and provide better fishing than do fingerling plantings. Planting "keeper" trout during the fishing season in waters which are overpopuluated with stunted trout as a result of too successful natural reproduction may be desirable, as these plantings should reduce the number of wild breeders and thus allow for better growth of the future progeny.

Planting "keeper" trout does "pep up the fishing," but apparently this stimulant works the same as morphine in man—there is a drain on the reserve which demands larger and repeated doses. If our conclusions are correct (more exact information will be available at the end of the 1938 fishing season), the eventual fate of a stream stocked with large trout would be somewhat as follows—few or no legal trout left to breed, few fish in the stream except those just planted from the hatcheries, and very few if any "lunkers" to provide the thrill anticipated by all trout fishermen while catching the 8- to 10-inch fish for the pan.

## Acknowledgments

The writers wish to express their appreciation to the Michigan Conservation Commission, especially Chairman William H. Loutit who has personally sponsored this project, for the opportunity to carry on the investigation. We also deeply appreciate the encouragement and help offered by F. A. Westerman and A. B. Cook of the Fish Division. Robert Fortney, District Supervisor of Fisheries Operations, efficiently organized the planting program and assisted in many ways. The State and later the U. S. Forest Service supplied the C.C.C. enrollees for the project. We are also indebted to our colleagues, Dr. Ralph Hile and Dr. R. W. Eschmeyer, for critical reading of the manuscript and for aid in interpretation of the data.

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## Discussion

Mr. T. C. Fearnow: I would like to ask whether or not, on the basis of Dr. Hazzard's findings, he would recommend that the stocking programs be divided into two separate units, one, the stocking of fingerlings for the production of fish along more or less natural lines; and second, the use of so-called market basket streams in which to dump our legal-sized fish for the fishermen to take immediately.

Dr. Hazzard: The plan is all right providing you can get the fishermen to pay what it costs to get those big fish.

Dr. J. S. Gutsell: I wonder, with the number of unmarked fish, how you determined which were the wild fish and which were not—simply by the coloring and general appearance?

Dr. Hazzard: We don't feel that anyone can distinguish by color with certainty the wild fish from the hatchery fish, but it is fair, if you mark one-third of the planting, to assume that the unmarked fish would be caught in the same proportion as the marked fish, and that is what we have done. In other words, the estimated total number removed by the fishermen would be three times the number of marked fish caught.

Mr. Fearnow: Within the last month I was approached by representatives of the organized sportsmen in one of the populous counties in my district with the request that a stream be set aside as a controlled fishing area and that a special permit at a cost of $1.00 be sold to cover the added cost of maintaining

that stream by planting legal-sized fish. The surprising thing about it is that a number of really good fishermen were interested in this project, and one of the arguments they advanced was that a development of that type would take away from the natural fishing streams a tremendous fishing pressure and would concentrate the "dubs" on that controlled area, where we could dump fish in weekly or monthly.

MR. C. O. HAYFORD: We have had considerable experience with this "big-fish" program in New Jersey over a period of years, and I think there are three different ways that it can be handled. First, we started planting direct from the hatchery. In a very short time it developed into a funeral procession. Instead of having flowers there were rods and dip nets.

Then we posted the streams and prohibited fishing for forty-eight hours from the time the fish were planted. We don't try to close off a whole stream. We close only sections of a stream. The third way is to close a whole stream for a certain period of time.

I made the test myself there, and with the "dumping" system I don't suppose I fished over 200 feet with a fly to catch my limit in probably less than twenty minutes. The next test I made was to take a boat and float that down the stream and throw out a fish, as I put it, for every rod and pole. The next day, after planting these fish in that way, I worked a mile of that stream and it took me over seven hours to catch eight trout. This shows that you can not catch the trout so easily if you go to the expense of scattering them very thinly.

Our trout, if planted as fingerlings in the spring of the year, will only be 5½ to 6½ inches long when 1 year old. I planted 10,000 fingerlings in a stream and the following spring I could get only twenty-seven legal-sized trout out of that stretch. In the hatcheries over that same period of time we can grow these fish to anywhere from 8 to 11 inches, with a few 12-inch fish.

I had experience in northern Maine and in New Jersey with the "big-fish" program. One private club in New Jersey tried the planting of small fish over a period of something like twenty years without increasing the catch. The catch was only a small proportion of the fish planted.

DR. DAVID S. SHETTER: Our experience in the distribution of fish by means of scattering from a boat has been quite similar to that of Mr. Hayford in New Jersey. The catch per hour was considerably less from boat plantings than "spot plantings," and I personally favor that method because it gives more fishermen a chance to get at the fish, instead of only those who can crowd around the quarter of a mile of stream on which the "spot plantings" might be made.

We had an interesting experience in the marking experiments that we conducted this spring before the season opened. Although I think you mentioned that you closed a stream for forty-eight hours after a planting, I hardly think that the two days will allow a fish enough time to become wild, because of 1,500 marked brook trout and rainbow trout that we put in on the first of April at least 400 were taken out on the very first day of the season.

MR. H. C. DAVIS: We have experimented extensively in California with the rearing and planting of fish in cooperation with the U. S. Bureau of Fisheries. I think our experience there demonstrates very clearly much of what these gentlemen have presented, and that is that the planting of aged fish is an entirely local problem for each individual stream. I can illustrate that best by a more or less true story.

The streams of southern California are so limited in their flow of water that we must plant aged fish. We will take, for example, a sunny Sunday morning in May. Mr. Los Angeles looks out of his window and for no good reason at

all discovers that there has been a cloudburst on the desert the night before and there is water in the Los Angeles River. By 9:30 o'clock, 20,000 telephone calls have come to the Fish and Game Commission to come out and plant some fish because there is water in the Los Angeles River. Since we have one of the most efficient departments in the country, by 10 o'clock a truckload has started out. We carry a siren on the trucks, by which, at the end of the planting, we let everybody know that the planting has been accomplished. By 11 o'clock the fish are caught out of the stream, and at noon the river has dried up again! (Laughter and applause)

THE PRESIDENT: That shows what California can do!

MR. F. A. WESTERMAN: Just one word in explanation of Dr. Shetter's last statement. I don't think he made it quite clear to you at all that in Michigan the trout season opens on the last day in April. He mentioned that the fish had been introduced on the first of April, so there is about a four-week interval between the time of planting and when the fishermen began removing the fish.

# DIURNAL ACTIVITY OF THE COMMON SUCKER, *CATOSTOMUS COMMERSONNII* (LACÉPÈDE), AND THE ROCK BASS, *AMBLOPLITES RUPESTRIS* (RAFINESQUE), IN MUSKELLUNGE LAKE[1]

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## Abstract

Gill nets set in Muskellunge Lake, Vilas County, Wisconsin, were examined at 2- to 4-hour intervals throughout ten 24-hour periods during the summers of 1933 to 1937 to determine the activity of suckers and rock bass during the day and night.

The rate at which suckers were captured at depths around 6 meters was highest during the periods 3 to 5 a.m. and 7 to 9 p.m. and lowest during the periods 8 a.m. to 4 p.m. and 10 p.m. to 2 a.m. The rate of capture was high at midday at depths around 8 meters. There is evidence that the suckers move inshore in the evening and offshore in the morning. Although the hourly fluctuations in the catch may have been caused by rhythmic changes in the activity of the fish, it seems more probable that they were caused by fluctuations in abundance in the vicinity of the nets which resulted from the inshore and offshore movements.

The rock bass were captured in far greater numbers at night than in the daytime. The rate of capture was highest between 7 and 9 p.m., but remained relatively high throughout the night. The rate increased slightly between 3 and 4 a.m. Apparently increased visibility was the chief cause of the decrease in the rate of capture during the day. However, there is evidence that rock bass undergo periodic changes in activity. The results offer very little evidence of daily inshore and offshore movements. Apparently the rock bass moved at random in the vicinity of the nets.

## Introduction

Although the seasonal and breeding migrations of fishes have received considerable attention, references to their daily movements are not numerous in the available literature. Evermann and Clark (1920) noted that many of the fishes of Lake Maxinkuckee, including suckers and rock bass, show a well marked inshore movement on still nights, especially during August and September. The yellow perch appears to migrate upward at night (Pearse and Achtenberg, 1920). Hickling (1927) stated that the hake is inactive by day but active by night, and that it shows indications of a nightly vertical migration. According to Johansen (1927), the herring shows a pronounced diurnal vertical migration. The younger stages in particular are more numerous in the upper water layers at night than in the daytime. Russell (1926a, 1926b, 1928, 1930) found indications of diurnal variations in the vertical distribution of the pelagic young of various teleostean fishes in the Plymouth area. Clupeids were many

[1]From the Limnological Laboratory of the Wisconsin Geological and Natural History Survey. Notes and reports No. 89.

**TABLE 1. NUMBERS OF SUCKERS AND ROCK BASS CAUGHT DURING EACH PERIOD**

| Set No. | Date | Depth (meters) | Time set | Time examined | No. of fish caught: Suckers | No. of fish caught: Rock Bass |
|---|---|---|---|---|---|---|
| 1 | July 19 and 20, 1933 | 6 | 8 a.m. | 10 a.m. | 0 | 0 |
| | | | | 1 p.m. | 0 | 0 |
| | | | | 4 p.m. | 0 | 0 |
| | | | | 7 p.m. | 0 | 0 |
| | | | | 9 p.m. | 16 | 14 |
| | | | | 1 a.m. | 0 | 7 |
| | | | | 3 a.m. | 0 | 5 |
| | | | | 5 a.m. | 14 | 7 |
| | | | | 8 a.m. | 5 | 5 |
| 2 | July 25 and 26, 1934 | 6 | 4 p.m. | 7 p.m. | 0 | 0 |
| | | | | 10 p.m. | 11 | 8 |
| | | | | 4 a.m. | 18 | 6 |
| | | | | 7 a.m. | 0 | 0 |
| | | | | 10 a.m. | 0 | 1 |
| | | | | 1 p.m. | 0 | 2 |
| | | | | 4 p.m. | 0 | 1 |
| 3 | August 3 and 4, 1934 | 6 | 4 p.m. | 7 p.m. | 0 | 0 |
| | | | | 10 p.m. | 8 | 15 |
| | | | | 1 a.m. | 0 | 15 |
| | | | | 4 a.m. | 2 | 4 |
| | | | | 7 a.m. | 5 | 1 |
| | | | | 10 a.m. | 1 | 0 |
| | | | | 1 p.m. | 0 | 0 |
| | | | | 4 p.m. | 1 | 0 |
| 4 | June 28 and 29, 1935 | 6 | 4 p.m. | 7 p.m. | 11 | 4 |
| | | | | 10 p.m. | 11 | 6 |
| | | | | 4 a.m. | 5 | 7 |
| | | | | 7 a.m. | 4 | 1 |
| | | | | 10 a.m. | 0 | 0 |
| | | | | 1 p.m. | 1 | 1 |
| | | | | 4 p.m. | 2 | 1 |
| 5 | July 5 and 6, 1935 | 6 | 4 p.m. | 8 p.m. | 7 | 1 |
| | | | | 12 midnight | 3 | 0 |
| | | | | 4 a.m. | 3 | 2 |
| | | | | 8 a.m. | 1 | 0 |
| | | | | 12 noon | 0 | 0 |
| | | | | 4 p.m. | 0 | 0 |
| 6 | July 10 and 11, 1935 | 4 | 8 a.m. | 12 noon | 0 | 1 |
| | | | | 4 p.m. | 1 | 0 |
| | | | | 8 p.m. | 3 | 2 |
| | | | | 12 midnight | 0 | 1 |
| | | | | 4 a.m. | 3 | 6 |
| | | | | 8 a.m. | 1 | 2 |
| 7 | July 16 and 17, 1935 | 6-8 | 10 a.m. | 2 p.m. | 9 | 0 |
| | | | | 6 p.m. | 3 | 0 |
| | | | | 10 p.m. | 4 | 5 |
| | | | | 2 a.m. | 2 | 4 |
| | | | | 6 a.m. | 9 | 10 |
| | | | | 10 a.m. | 6 | 1 |
| 8 | July 18 and 19, 1935 | 8 | 10 a.m. | 2 p.m. | 5 | 1 |
| | | | | 6 p.m. | 0 | 1 |
| | | | | 10 p.m. | 2 | 2 |
| | | | | 2 a.m. | 2 | 1 |
| | | | | 6 a.m. | 6 | 6 |
| | | | | 10 a.m. | 1 | 3 |
| 9 | July 16 and 17, 1936 | 6 | 11 a.m. | 2 p.m. | 0 | 0 |
| | | | | 5 p.m. | 0 | 0 |
| | | | | 8 p.m. | 4 | 11 |
| | | | | 11 p.m. | 1 | 6 |
| | | | | 2 a.m. | 0 | 1 |
| | | | | 5 a.m. | 5 | 2 |
| | | | | 8 a.m. | 1 | 0 |
| | | | | 11 a.m. | 0 | 0 |
| 10 | June 14 and 15, 1937 | 5-8 | 1 p.m. | 5 p.m. | 3 | 0 |
| | | | | 9 p.m. | 7 | 5 |
| | | | | 5 a.m. | 7 | 4 |
| | | | | 9 a.m. | 2 | 0 |
| | | | | 1 p.m. | 1 | 1 |

times more abundant in the catches at night than in the daytime. Spencer (1929) obtained graphic records of the swimming movements of four species of fresh-water fishes during periods of several days' duration. The carp and mud minnow were more active at night than during the day. The pumpkinseed was active during the day but showed a period of almost total quiescence at night. The rock bass showed little periodic variation in activity. Hart (1931) found that in Lake Nipigon greater numbers of coregonid fishes were captured at night than in the daytime, and concluded that these fishes show considerable activity at night. He noted that suckers, pike, saugers, and perch were captured in rather greater numbers in the daytime. The experiments to be reported in this paper were designed to determine the activity of suckers and rock bass during the day and night.

## Method

Gill nets were set parallel to the shoreline in Muskellunge Lake, Vilas County, Wisconsin, at depths ranging around 6 meters. Six nets were used in each set. Each net was 150 feet long and 6 feet deep; the mesh sizes were ¾, ⅞, 1, 1⅛, 1¼ and 1½ inches, bar measure. The nets were examined at 2- to 4-hour intervals during each 24-hour set. The fish captured during the preceding 2- to 4-hour period were removed each time the nets were examined. Records were kept of the number of each species caught. Ten sets were made during the years 1933-1937. The dates, depths of water, and numbers of suckers and rock bass removed from the nets at each examination are listed in Table 1. The number of fish caught per hour was computed for each 2- to 4-hour period of each 24-hour set. The sets were made only when the weather was clear and calm.

The catches contained yellow perch and smallmouth black bass in addition to suckers and rock bass, but the perch catches were too irregular and the smallmouth bass catches too small to be studied by this method.

## Hourly Fluctuations in the Catch of Suckers and Rock Bass

The data on the suckers are arranged in Table 2 according to the calculated number of fish caught during each hour of each 24-hour set. The figure recorded for each time listed represents the calculated number of fish caught during the hour preceding that time. Thus, since fourteen suckers were captured between 3 and 5 a.m. in Set 1, the calculated number of fish caught per hour is seven. The calculated number of fish caught between 4 and 5 a.m. is listed at 5 a.m. In order to compare the various periods, it is necessary to assume that the fish taken in each period were captured at a uniform rate throughout the period. The sets are arranged in chronological order. The first column of averages at the right of Table 2 shows the average catch for each hour for all sets combined. It will be

**TABLE 2. AVERAGE NUMBER OF SUCKERS CAUGHT DURING EACH HOUR OF EACH SET. SEE TABLE 1 FOR DATE OF EACH SET**

| Hour | Number of suckers per hour in Set No. 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Average catch per hour: All sets | Perfect sets[1] | Six-meter sets |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12 m. | 0.0 | 3.0 | 0.0 | 0.8 | 0.8 | 0.0 | 0.5 | 0.5 | 0.0 | 0.9 | 0.65 | 0.25 | 0.76 |
| 1 a.m. | 0.0 | 3.0 | 0.0 | 0.8 | 0.8 | 0.8 | 0.5 | 0.5 | 0.0 | 0.9 | 0.72 | 0.36 | 0.76 |
| 2 a.m. | 0.0 | 3.0 | 0.7 | 0.8 | 0.8 | 0.8 | 0.5 | 0.5 | 0.0 | 0.9 | 0.79 | 0.45 | 0.84 |
| 3 a.m. | 0.0 | 3.0 | 0.7 | 0.8 | 0.8 | 0.8 | 2.2 | 1.5 | 1.7 | 0.9 | 1.23 | 1.08 | 1.15 |
| 4 a.m. | 7.0 | 3.0 | 0.7 | 0.8 | 0.8 | 0.8 | 2.2 | 1.5 | 1.7 | 0.9 | 1.93 | 2.08 | 2.32 |
| 5 a.m. | 7.0 | 0.0 | 1.7 | 1.3 | 0.2 | 0.2 | 2.2 | 1.5 | 1.7 | 0.9 | 1.68 | 2.08 | 1.97 |
| 6 a.m. | 1.7 | 0.0 | 1.7 | 1.3 | 0.2 | 0.2 | 2.2 | 1.5 | 0.3 | 0.5 | 0.98 | 1.13 | 0.84 |
| 7 a.m. | 1.7 | 0.0 | 1.7 | 1.3 | 0.2 | 0.2 | 1.5 | 0.2 | 0.3 | 0.5 | 0.78 | 0.85 | 0.84 |
| 8 a.m. | 1.7 | 0.0 | 0.7 | 0.0 | 0.2 | 0.2 | 1.5 | 0.2 | 0.3 | 0.5 | 0.54 | 0.70 | 0.49 |
| 9 a.m. | 0.0 | 0.0 | 0.7 | 0.0 | 0.0 | 0.0 | 1.5 | 0.2 | 0.0 | 0.5 | 0.29 | 0.35 | 0.11 |
| 10 a.m. | 0.0 | 0.0 | 0.7 | 0.0 | 0.0 | 0.0 | 1.5 | 0.2 | 0.0 | 0.2 | 0.27 | 0.35 | 0.11 |
| 11 a.m. | 0.0 | 0.0 | 0.0 | 0.3 | 0.0 | 0.0 | 2.2 | 1.2 | 0.0 | 0.2 | 0.41 | 0.50 | 0.05 |
| 12 n. | 0.0 | 0.0 | 0.0 | 0.3 | 0.0 | 0.0 | 2.2 | 1.2 | 0.0 | 0.2 | 0.41 | 0.50 | 0.05 |
| 1 p.m. | 0.0 | 0.0 | 0.0 | 0.3 | 0.0 | 0.2 | 2.2 | 1.2 | 0.0 | 0.2 | 0.43 | 0.54 | 0.05 |
| 2 p.m. | 0.0 | 0.0 | 0.7 | 0.7 | 0.0 | 0.2 | 2.2 | 1.2 | 0.0 | 0.8 | 0.52 | 0.63 | 0.22 |
| 3 p.m. | 0.0 | 0.0 | 0.7 | 0.7 | 0.0 | 0.2 | 0.8 | 0.0 | 0.0 | 0.8 | 0.31 | 0.24 | 0.22 |
| 4 p.m. | 0.0 | 0.0 | 0.7 | 0.7 | 0.0 | 0.2 | 0.8 | 0.0 | 0.0 | 0.8 | 0.31 | 0.24 | 0.22 |
| 5 p.m. | 0.0 | 0.0 | 0.0 | 3.7 | 1.8 | 0.8 | 0.8 | 0.0 | 0.0 | 0.8 | 0.78 | 0.46 | 0.90 |
| 6 p.m. | 0.0 | 0.0 | 0.0 | 3.7 | 1.8 | 0.8 | 0.8 | 0.0 | 1.3 | 1.8 | 1.00 | 0.65 | 1.12 |
| 7 p.m. | 0.0 | 0.0 | 0.0 | 3.7 | 1.8 | 0.8 | 1.0 | 0.5 | 1.3 | 1.8 | 1.08 | 0.76 | 1.12 |
| 8 p.m. | 8.0 | 3.7 | 2.7 | 3.7 | 1.8 | 0.8 | 1.0 | 0.5 | 1.3 | 1.8 | 2.51 | 2.29 | 3.51 |
| 9 p.m. | 8.0 | 3.7 | 2.7 | 3.7 | 0.8 | 0.0 | 1.0 | 0.5 | 0.3 | 1.8 | 2.23 | 1.89 | 3.18 |
| 10 p.m. | 0.0 | 3.7 | 2.7 | 3.7 | 0.8 | 0.0 | 1.0 | 0.5 | 0.3 | 0.9 | 1.35 | 0.75 | 1.85 |
| 11 p.m. | 0.0 | 3.0 | 0.0 | 0.8 | 0.8 | 0.0 | 0.5 | 0.5 | 0.3 | 0.9 | 0.68 | 0.30 | 0.82 |

[1]See text for definition of "perfect set."

noted that although suckers were captured during each hour of the day, they were captured in greatest numbers between the hours of 3 and 5 a.m. and 7 and 9 p.m. In each of three sets (Sets 2, 4 and 10) one examination (1 a.m.) was missed, so that the number of fish recorded at the next examination represents the catch of two periods instead of one. Since any difference in the rate of capture which might have appeared between the two periods is thus obscured, the second column of averages is included at the right of Table 2 to show the average catch per hour for all except the three imperfect sets. In this column the differences are more clearly defined, particularly during the period 9 p.m. to 2 a.m.

The first two columns of averages show a slight increase in the rate of capture during the middle of the day. This increase is caused by the large midday catches of Sets 7 and 8, which were made in slightly deeper water than the rest. In order to eliminate discrepancies traceable to differences in the depths in which the catches were made, the averages of the data from all 6-meter sets (Sets 1, 2, 3, 4, 5 and 9) are shown in the third column of averages in Table 2. Figure 1 is based upon these data. It is evident that at 6 meters the rate of capture fell off sharply during the daytime.

The corresponding data for the rock bass are listed in Table 3. The average catch for each hour for all sets is shown in the first column of averages at the right. The average catch per hour for all except the three imperfect sets is given in the second column of averages. Figure 2 is based upon the data in the second column. This figure

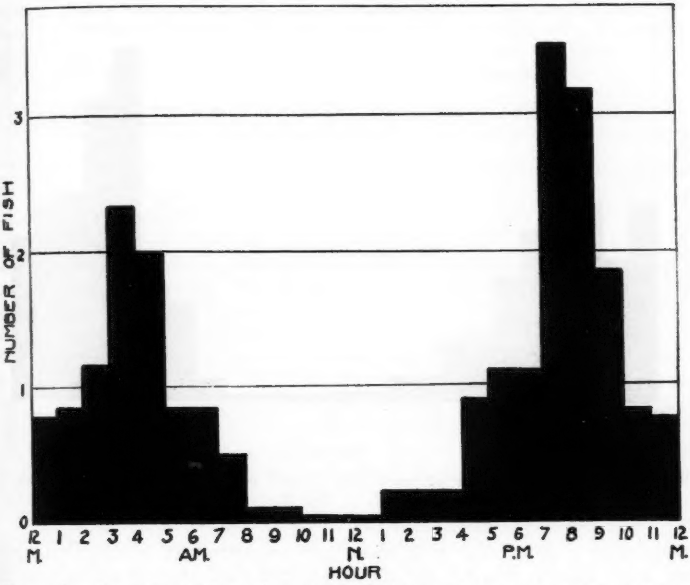


Figure 1.—Average number of suckers caught per hour at 6 meters based on sets 1, 2, 3, 4, 5 and 9.

**TABLE 3. AVERAGE NUMBER OF ROCK BASS CAUGHT DURING EACH HOUR OF EACH SET. SEE TABLE 1 FOR DATE OF EACH SET**

| Hour | Number of rock bass per hour in Set No. 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Average catch per hour: All sets | Perfect sets[1] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12 m. | 1.8 | 1.0 | 5.0 | 1.7 | 0.0 | 0.2 | 1.0 | 0.2 | 0.3 | 0.5 | 1.17 | 1.22 |
| 1 a.m. | 1.8 | 1.0 | 5.0 | 1.7 | 0.5 | 1.5 | 1.0 | 0.2 | 0.3 | 0.5 | 1.35 | 1.48 |
| 2 a.m. | 2.5 | 1.0 | 1.3 | 1.7 | 0.5 | 1.5 | 1.0 | 0.2 | 0.3 | 0.5 | 1.06 | 1.06 |
| 3 a.m. | 2.5 | 1.0 | 1.3 | 1.7 | 0.5 | 1.5 | 2.5 | 1.5 | 0.7 | 0.5 | 1.37 | 1.50 |
| 4 a.m. | 3.5 | 1.0 | 1.3 | 1.7 | 0.5 | 1.5 | 2.5 | 1.5 | 0.7 | 0.5 | 1.47 | 1.64 |
| 5 a.m. | 3.5 | 0.0 | 0.3 | 0.3 | 0.0 | 0.5 | 2.5 | 1.5 | 0.7 | 0.5 | 0.98 | 1.28 |
| 6 a.m. | 1.7 | 0.0 | 0.3 | 0.3 | 0.0 | 0.5 | 2.5 | 1.5 | 0.0 | 0.0 | 0.68 | 0.93 |
| 7 a.m. | 1.7 | 0.0 | 0.3 | 0.3 | 0.0 | 0.5 | 0.2 | 0.8 | 0.0 | 0.0 | 0.38 | 0.50 |
| 8 a.m. | 1.7 | 0.3 | 0.0 | 0.0 | 0.0 | 0.5 | 0.2 | 0.8 | 0.0 | 0.0 | 0.35 | 0.45 |
| 9 a.m. | 0.0 | 0.3 | 0.0 | 0.0 | 0.0 | 0.2 | 0.2 | 0.8 | 0.0 | 0.0 | 0.16 | 0.18 |
| 10 a.m. | 0.0 | 0.3 | 0.0 | 0.0 | 0.0 | 0.2 | 0.2 | 0.8 | 0.0 | 0.2 | 0.18 | 0.18 |
| 11 a.m. | 0.0 | 0.7 | 0.0 | 0.3 | 0.0 | 0.2 | 0.0 | 0.2 | 0.0 | 0.2 | 0.18 | 0.07 |
| 12 n. | 0.0 | 0.7 | 0.0 | 0.3 | 0.0 | 0.2 | 0.0 | 0.2 | 0.0 | 0.2 | 0.18 | 0.07 |
| 1 p.m. | 0.0 | 0.7 | 0.0 | 0.3 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 0.2 | 0.15 | 0.04 |
| 2 p.m. | 0.0 | 0.3 | 0.0 | 0.3 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.09 | 0.04 |
| 3 p.m. | 0.0 | 0.3 | 0.0 | 0.3 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.09 | 0.04 |
| 4 p.m. | 0.0 | 0.3 | 0.0 | 0.3 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.09 | 0.04 |
| 5 p.m. | 0.0 | 0.0 | 0.0 | 1.3 | 0.2 | 0.5 | 0.0 | 0.2 | 0.0 | 0.0 | 0.23 | 0.14 |
| 6 p.m. | 0.0 | 0.0 | 0.0 | 1.3 | 0.2 | 0.5 | 0.0 | 0.2 | 3.7 | 1.2 | 0.73 | 0.67 |
| 7 p.m. | 0.0 | 0.0 | 0.0 | 1.3 | 0.2 | 0.5 | 1.2 | 0.5 | 3.7 | 1.2 | 0.88 | 0.88 |
| 8 p.m. | 7.0 | 2.7 | 5.0 | 2.0 | 0.2 | 0.5 | 1.2 | 0.5 | 3.7 | 1.2 | 2.41 | 2.60 |
| 9 p.m. | 7.0 | 2.7 | 5.0 | 2.0 | 0.0 | 0.2 | 1.2 | 0.5 | 2.0 | 1.2 | 2.19 | 2.24 |
| 10 p.m. | 1.8 | 2.7 | 5.0 | 2.0 | 0.0 | 0.2 | 1.2 | 0.5 | 2.0 | 0.5 | 1.59 | 1.54 |
| 11 p.m. | 1.8 | 1.0 | 5.0 | 1.7 | 0.0 | 0.2 | 1.0 | 0.2 | 2.0 | 0.5 | 1.34 | 1.46 |

[1]See text for definition of "perfect set."

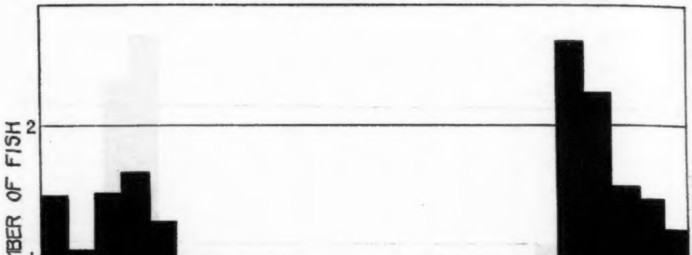


**Figure 2.—Average number of rock bass caught per hour based on sets 1, 3, 5, 6, 7, 8 and 9.**

shows that most of the rock bass were captured at night, that very few were caught during the daytime, and that they were caught in greatest numbers between 7 and 9 p.m. Since depth appeared to have no pronounced effect upon the rock bass catches, the data were not separated on this basis.

In all sets except the first, the side from which each fish entered the net was noted whenever possible in order to determine whether the fish was moving inshore or offshore when caught. Altogether, the direction of movement was determined for 127 suckers and 106 rock bass. The results are summarized in Table 4. For the preparation

**TABLE 4. NUMBERS OF SUCKERS AND ROCK BASS MOVING INSHORE AND OFFSHORE WHEN CAUGHT**

| | Time of Capture | | | |
|---|---|---|---|---|
| | 12 n. to 12 m. | | 12 m. to 12 n. | |
| Species | Moving inshore | Moving offshore | Moving inshore | Moving offshore |
| Sucker | 50 | 27 | 12 | 38 |
| Rock bass | 39 | 27 | 18 | 22 |

of this table, the day was divided into two parts, noon to midnight and midnight to noon. Data were taken only from the observation periods which fell within these limits; the periods which included noon or midnight were omitted. The majority of the suckers caught

between noon and midnight was moving inshore, and most of those caught between midnight and noon were moving offshore. The numbers of rock bass moving in each direction were more nearly equal. The differences are hardly great enough to be significant.

### SIGNIFICANCE OF THE HOURLY FLUCTUATIONS IN THE CATCH OF SUCKERS

Before it may be concluded that larger catches during certain hours indicate increased activity in the vicinity of the nets, several other possible explanations for the periodic changes in the rate of capture must be considered. The consistency with which the rate of capture tended to be highest at approximately the same hours throughout the series demonstrates that the fluctuations in the catch can not be attributed to mere chance. The results depart from the general trend to an appreciable extent in but two sets, 7 and 8, in which the rate of capture at midday approaches that of the early morning. Although the available data offer no completely satisfactory explanation for these large midday catches, it is quite possible that they are the result of the greater depths at which the nets were set. This interpretation is supported by the catch records reported by Hart (1931), who took more suckers at depths of 9 to 20 meters during the daytime than at night.

The possibility that some of the fish moving across the line of the nets may have passed above the nets must be considered also. It is unlikely that any suckers passed above the nets, for of several thousand suckers captured in gill nets during the years 1932 to 1937, very few, if any, were found to be more than 18 inches above the lead line.

Since the rate of capture was lowest during the middle of the day, it is possible that increased visibility enabled the suckers to avoid the nets during the day. However, if increased visibility had been the cause of the decrease in the rate of capture, the greatest catches should have been made at night. The fact that the rate of capture decreased markedly during the night (Table 2, averages of perfect sets) demonstrates that the fluctuations in the hourly catch were not the result of variations in visibility. Since the amount of light which penetrates into the water is greatest during the period 10 a.m. to 2 p.m., the large midday catches of Sets 7 and 8 also indicate that visibility had no effect upon the rate of capture. The results of Sets 7 and 8 are also subject to another interpretation. Of the total sunlight which strikes the surface of Muskellunge Lake, about 1.8 per cent penetrates to a depth of 6 meters and about 0.7 per cent reaches 8 meters (Birge and Juday, 1932). Therefore, since the light reaching 8 meters is less than half that found at 6 meters, the large midday catches of Sets 7 and 8 may have been the result of low visibility at 8 meters. However, if the suckers were captured at a depth of 8 meters solely because of their inability to see the nets, the rate

should have remained constant throughout the 24-hour period. The fluctuations in the rate of capture were pronounced in both sets. The rate was low at night and high at dawn as usual, and although it was high during the period 10 a.m. to 2 p.m., it was much lower during the hours before and after this period. Although light may be the ultimate factor governing the activity of these fishes, it may be concluded that variations in visibility did not cause the hourly fluctuations in the rate at which suckers were captured.

Two possible explanations for the fluctuations in the rate of capture remain to be considered. Since rhythmic changes in activity have been reported for the hake (Hickling, 1927), carp, mud minnow and pumpkinseed (Spencer, 1929), the hourly fluctuations in the rate of capture may have been caused by rhythmic changes in the activity of the sucker over the 24-hour period. The suckers may have been more active during the periods 3 to 5 a.m. and 7 to 9 p.m. than during the periods in which the rate of capture was low. This explanation is supported by the work of Clausen (1936), who found that the amount of oxygen consumed per hour by fishes inhabiting relatively quiet waters fluctuates rhythmically over a 24-hour period. However, the large midday catches of Sets 7 and 8 show that the suckers were not less active during the day at depths around 8 meters. It seems more probable that the fluctuations in the catch were caused by fluctuations in the abundance of the suckers in the vicinity of the nets as a result of daily inshore and offshore movements. According to the data shown in Table 4, the suckers tend to move inshore in the evening and offshore in the morning. The large catches made in the evening and early morning suggest that the suckers are most abundant at depths around 6 meters between 7 and 8 p.m. as they move inshore, and between 3 and 5 a.m. as they move offshore. The large midday catches of Sets 7 and 8 indicate that the fish reach depths around 8 meters during the middle of the day. This interpretation is in agreement with the conclusion of Evermann and Clark (1920) that many lake fishes move inshore at night. It is also in harmony with the catch records reported by Hart (1931), which show that more suckers were captured in Lake Nipigon during the day than at night at depths between 9 and 20 meters.

## Significance of the Hourly Fluctuations in the Catch of Rock Bass

Since the rate of capture was highest at approximately the same hours throughout the series, the fluctuations in the catch of rock bass can not be attributed to chance. It also appears that the fluctuations were not caused by inshore and offshore movements, for the data listed in Table 4 indicate that the rock bass tended to move at random in the vicinity of the nets. Moreover, the midday catches made at depths around 8 meters were not larger than those made in shallower

water. However, the significance of the catches is obscured by the possibility that some of the rock bass passed over the nets. This possibility is suggested by the fact that rock bass were captured at all levels of the nets. Apparently changes in visibility over the 24-hour period had a pronounced effect upon the catch. The rate of capture was high throughout the night, fell steadily during the day as the visibility increased and became high again toward evening as the visibility decreased. However, the occurrence of a peak in the rate of capture between 7 and 8 p.m., followed by a steady decrease toward midnight, demonstrates that visibility was not the sole factor responsible for the hourly fluctuations in the catch (Figure 2). Although Spencer (1929) found little periodic variation in the activity of the rock bass, this peak in the rate of capture suggests that rock bass are more active in the evening than during the night. The fact that the rate of capture increased slightly between 3 and 4 a.m. indicates that the rock bass are more active at dawn than at night.

We wish to thank Dr. C. Juday for his interest in this study and for providing the necessary equipment and Dr. Edward Schneberger, Dr. S. X. Cross, and Mr. David Frey for assistance with several of the sets.

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# RESULTS OF SEVEN YEARS' INTENSIVE STOCKING OF SPAVINAW LAKE; AN IMPOUNDED RESERVOIR

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Abstract

The City of Tulsa, Oklahoma, operates a hatchery which has produced an annual crop of 400,000 fingerling fish, principally black bass, crappies, and bream. Most of the fish have been planted in Spavinaw Lake, an impounded reservoir from which the City of Tulsa secures its water supply.

The increase in the catch of fish has not been in proportion to the number of fish planted. Many anglers still make poor catches. Studies of the lake show that bass are plentiful but hard to catch. Studies made at the municipal hatchery, demonstrate that the intelligence of bass has been grossly underestimated. Additional evidence was also obtained by the catch records from a group of experienced fishermen. Expert anglers who know the lake and the habits of bass always make good catches.

For the past seven years the City of Tulsa has operated a municipal fish hatchery to produce fingerling black bass and other pond fishes for stocking Spavinaw Lake from which the city draws its water supply.

Spavinaw Lake is an artifical reservoir 1,800 acres in area, impounding 30,660 acre feet of water. It is located in the Ozark foothills and is fed by springs. The water is clear, pure, and unpolluted. The 400 square miles of watershed are largely an uncultivated wilderness. The basin of the lake is a typical mountain valley, with a rather steep shoreline, and there is little shallow water except in the hollows and in the extreme upper end of the basin. Vegetation of many types flourishes in the shallow areas and on a narrow bench around the entire lake. This bench which has been formed by ice and wave action is constantly widening as time goes on.

Spavinaw Lake is considered an ideal habitat for black bass and other warm-water fishes. Because of its popularity as a resort, its splendid fishing, and the large area it serves, the sportsmen of Tulsa were naturally enthusiastic over the hatchery program. The sportsmen, characteristically, expected fishing to improve by leaps and bounds as soon as the hatchery program was begun.

Since municipal lakes and reservoirs are impounded for the purpose of supplying pure water for domestic purposes, fish production must be considered a secondary or incidental usage, and fishing must be conducted in a manner that will not in any way affect the sanitary condition of the water.

The question often arises as to whether or not it is advisable, or practical, to plant fish in municipal waters. We have found that as a general rule any body of water will become stocked with fish by natural distribution in a very few years, and these fish are usually undesirable species such as gizzard shad, carp, bullheads, suckers, and small

sunfish. It seems only reasonable, therefore, that desirable game species should be introduced to forage upon and control the rough-fish population. Well-regulated fishing need not endanger the quality of the water. On the contrary, in Tulsa we have found that it is more desirable to permit the use of the reservoirs for recreational purposes, under supervision and where sanitary facilities are provided, than to have the public concentrate on a stream above the lake outside of the jurisdiction of the city, where sanitary facilities are lacking.

The City of Tulsa maintains its own chemical laboratory and hourly tests are made of the untreated water and the delivered water. The monthly averages of turbidity and *Bacillus coli* indices of Table 1 were supplied by the city chemist, Mr. A. B. Jewell.

**TABLE 1. MONTHLY AVERAGES OF TURBIDITY AND BACILLUS COLI CONTENT OF THE NATURAL WATER AND TREATED WATER OF SPAVINAW LAKE**

| Month | Turbidity | Lake water—B. coli index per 100 cubic centimeters | Delivered water—B. coli index per 100 cubic centimeters |
|---|---|---|---|
| January | 6 | 1.5 | 0.0 |
| February | 4 | 1.1 | 0.0 |
| March | 50 | 19.6 | 0.0 |
| April | 60 | 68.0 | 0.0 |
| May | 14 | 57.0 | 0.0 |
| June | 65 | 125.0 | 0.0 |
| July | 40 | 18.0 | 0.0 |
| August | 5 | 18.5 | 0.0 |
| September | 4 | 4.8 | 0.0 |
| October | 6 | 10.7 | 0.0 |
| November | 10 | 11.2 | 0.0 |

This work shows that the *B. coli* index is roughly proportional to the turbidity of the water. Local rains do not materially affect the turbidity of Spavinaw Lake because most of the immediate watershed is heavily timbered. Turbidity is caused by the inflow of mud from Spavinaw Creek during the periods of heavy run-off in the farming region of Northwestern Arkansas.

Whatever pollution is received originates from sources beyond the control of the city. Apparently no amount of local fishing, or other use of the reservoir, has any effect on the count of *B. coli*. No cottages are permitted within 600 feet of the lake, and no camping or swimming is permitted in the area. Fishing and boating are permitted during daylight hours only. The public has been very generous in cooperating with the authorities regarding the intelligent use of the reservoir. This relationship brings about a more friendly attitude between the citizens and the officials of the Water Department. The tax payers are more tolerant of the burden of bonded indebtedness because they are allowed to enjoy and receive full use of their water system.

During the past seven years a total of 2,650,000 fingerling fish has

been planted in Spavinaw Lake. Of the total, 630,000 were largemouth bass 4 to 10 inches long. The average annual stocking rate is 195 fish per acre of surface area.

The annual catch has not been determined accurately. Efforts to obtain a complete creel census have not been entirely satisfactory. There is a reluctance on the part of most anglers to take the time to fill out the cards. We attribute this fact largely to the number of non-resident anglers who fish on Spavinaw Lake. However, a representative group of Tulsa anglers makes regular reports. We are of the opinion that a census of regular patrons who fish weekly, and really know how to fish, is more valuable, and presents a more accurate record of actual conditions, than the reports of transients and non-residents who do not know the lake and may not know how to fish.

As nearly as can be computed from the reports received, and from observations by our patrolman, the catch of black bass approximates 500 per week. Since the fishing season covers twenty-five weeks, an annual catch of approximately 12,500 black bass is indicated. This total does not include the fish returned to the water. What happens to all those fish we plant each year, and why does the catch fail to improve in proportion to the number stocked? That is the common question asked by many anglers, and the problem we have been studying from year to year. We believe the answer is quite obvious.

Our statistics show that the catch of large bass is increasing each season. The lake has a heavy population of bass each weighing 5 pounds or more. They are taken constantly by many anglers who have devised special trolling equipment. Hundreds are released from the traps and nets of the commercial fisherman employed to control the large carp population.

Close observation has shown that large bass select a certain area, and occupy it as a sort of "Lord of their domain" until captured. Large 5- to 9-pound bass range in age from 4 to 10 years, according to our amateur scale readings. As the bass grow older they become surprisingly "angler conscious." Their knowledge of the art of self preservation improves with age and was demonstrated by comparative tests of hatchery yearlings and adults.

Naturally, fingerlings and yearlings planted in the lake must be wary to escape destruction. They are besieged on one side by the large bass and on the other by an army of anglers. The development of their cunning to a high degree of perfection probably limits their occurrence in the angler's catches. We found that by sitting quietly in a boat, and flipping pebbles into the water we could attract dozens of bass to our boat. Minnows flipped overboard were seized at once and the congregated bass remained to see how long our generosity would last. A fly or spinner cast among them received the same attention. However, when an unlucky specimen was hooked the rest vanished. Continued casting was useless until we moved to a new location, when the above procedure could be repeated. This type of observation can be repeated

at almost any point on the lake on days when there are few fishermen along the shoreline.

Records reveal that on days of heavy fishing, Friday, Saturday, and Sunday, the catch per person is very low. This poor catch is not the result of an abundance of poor or mediocre fishermen. The best anglers have learned that they cannot always catch fish, particularily bass, when there is a crowd on the lake. The big catches are made on Tuesday, Wednesday, and Thursday, when the number of anglers is at a minimum. Everyone reports seeing plenty of bass, but few catches are made on week-ends.

We conducted several tests and recorded observations on the learning capacity or ability of adult bass. Dr. T. H. Langlois, who would call it "Social Behavior," has no doubt observed these traits many times.

At the Tulsa hatchery adult bass have been fed cubes of cooked mash for many years. The method was described and demonstrated during the 1935 meeting of this Society in Tulsa. Consequently the adult bass are easily observed and studied. It is remarkable how soon these bass learn the exact time of feeding. They are fed at 8:30 each morning, and a few minutes before that time they begin to congregate at the feeding place at the outlet kettles where the feeder can walk out some distance from the banks. When the bass feel, or hear, the feeder's footsteps, they begin crowding and circling the outlet structure. If a stranger approaches the pond the fish are on guard at once. They line up at a safe distance, and keep backing away. They will feed, however, but not nearly as eagerly as when they are fed by the customary person.

The following test has been repeated many times during the past several years. There are always a few bass present that have lost one, and occasionally both eyes. These fish cannot compete with the others for the cubes of food. If the blind fish are observed carefully and a cube of food is thrown to one side they soon learn to slip away from the others and receive their portion of food unmolested. At present one bass in particular, blind in one eye, circles around behind the outlet kettle as soon as we begin to feed the others. A few cubes of food are dropped nearby, and it soon goes its way happy and grateful.

Another example of the power of observation of bass is demonstrated by another test. Visitors at the hatchery continually entice the bass to strike at articles thrown into the water. Clover blossoms and tax tokens are the most popular items. An object thrown among the bass will be taken and dropped by two or three fish before the remainder learn that they are being tricked. They are not frightened, but for the rest of the day they will not strike at anything thrown into the water. Even minnows and crayfish are refused.

We have attempted in past years to fish the adult bass out of the spawning ponds to make room for fingerlings. The practice has been abandoned because the fish outwitted us. When a spinner is cast to

tame brood fish, naturally the first cast receives a vicious strike. By the time the hooked fish is removed the others have retreated to their respective hiding places. Occasionally we could catch two or three bass from a half-acre pond where a hundred were being fed daily. After attempts to catch them, the bass were shy and refused to appear at feeding time for at least three days. Apparently they can remember the incident for that length of time.

These tests and observations have been made many times over a period of years, and are not rare instances. We are convinced that in lakes and ponds where the fishing is heavy, and steady, the bass become familiar with the usual type of fishing, and ordinary tactics will not lure them to strike. We believe that the intelligence of the bass is the limiting factor in the catch. Bass fishing in Spavinaw Lake has been maintained and improved slowly. There is an abundance of bass present and we know that increasing the bass population of the lake does not result in a proportionate increase in the catch.

Crappies and bluegills do not respond to domestication. We can feed bluegills artificial food, and observe them in much the same manner as black bass, but they do not show much individuality. The crappie is sullen and shy, apparently too stupid to flee from danger. Both crappies and bluegills are taken by the thousands each week from Spavinaw Lake in spite of large crowds, fast motor boats, and general pandemonium. When bass are not striking the crappies can always be depended upon to fill the creel.

We learned that the crappie and bluegill were unable to compete with the bass for the desirable spawning areas which are limited to the bays and the upper end of the lake. As a result these species spawned around the entire shoreline, and closing the bays alone offered them little protection. We declared a closed season on these popular pan fishes for the entire lake during the month of May. We hope to make the closed season an annual affair since there is no state-wide ban on fishing.

After having written these observations concerning the intelligence of black bass, we are wondering what value the information might have. The writer is only an amateur who has been fortunate enough to receive compensation for his efforts. The information is transmitted to those to whom it may be of significance and who may find it of some practical value.

We have made use of these observations as a means of interesting and impressing the public with various factors of fisheries management, and the relationship of these factors to practical results. In order to interest the average angler we must first attract his attention by means of something unusual, or entertaining, concerning fish and their habits. Perhaps this may be accomplished by suggesting new tactics or methods of fishing that will increase the angler's catch. Such information must be popular and very elementary.

An attempt is made to inform the public concerning our plans and

program. The necessity of a constant program and the significance of their individual cooperation are emphasized. Civic groups and conservation clubs are contacted as often as time permits. Many of the organizations have committees that assist in maintaining a permanent, progressive program. Motion pictures and lantern slides are shown at every opportunity. The writer is working on a collection of Oklahoma fishes, and is photographing and preserving the specimens. The preserved specimens are exhibited and live specimens are held in aquaria at the hatchery. Merchants who have aquarium displays in their show windows are supplied with specimens.

We believe that the proper procedure for the fish-culturist is to show his products to the anglers, explain his plans, outline the results, acknowledge the anglers' views, and strive not only for better fishing, but also for better fishermen.

The use of municipal reservoirs must be governed by existing conditions in each individual body of water. Caution should be exercised in opening reservoirs to the public for fishing. The size and characteristics of the lake in relation to the number and *character of the people* who enjoy its facilities must determine the regulations governing the use of the lake.

Complete authority must be vested in the custodian and patrolman. The anglers should supply the funds for this supervision. In the Tulsa system the cost of propagation and management is met by charging anglers a fee of twenty-five cents for daily fishing permits.

We cannot over-emphasize the importance of educational activities in connection with fisheries management. We try to interest the anglers in the fundamentals of water farming. We prefer the term water farming to fish culture because almost everyone understands that there are certain practices involved in *farming* that contribute toward a good yield or harvest, and that fish are a crop that respond to cultivation, and like any crop must be harvested at the peak of their usefulness.

The use of municipal water supplies for recreational purposes must be based on a rigid management program rather than on an intensive propagation program, because many fish-cultural methods cannot be applied to the sanitary water-works system.

## Discussion

Mr. Eugene Surber: Last year Dr. Gutsell and I studied the growth of trout planted in 1935 and 1936 in the St. Mary's River near Staunton, Virginia. We made the trips at intervals of about six weeks to obtain catches of trout for the construction of a growth curve. It was apparent they were not growing as rapidly as expected.

While fishing for the trout a peculiar psychological behavior on the part of the trout in taking artificial lures was noted. If, on encountering a number of trout, I was successful in hooking the first one, I could catch as many as five or six in succession. If I missed the first one no others were taken.

While fishing in Canada I noted at that time of the year that the trout would not rise to a fly, but could be caught readily with worms.

MR. WILLIAM ADAMS: I am happy to say that as close as the water supply is to the City of New York, the Water Commission has shown a great liberality and fairness in trying to preserve as much public fishing as possible in that water supply. About how far is this reservoir from the main intakes of the City of Tulsa?

MR. ALDRICH: The reservoir is located 65 miles northeast of Tulsa, in the Ozark foothills. The water goes to Tulsa through a 60-inch concrete conduit and into two auxiliary reservoirs. Even the two reservoirs of some 300 acres on the outskirts of the city have been stocked and we encourage fishing in them also.

MR. ADAMS: The main reservoir is not treated in any way? I presume the water is chlorinated after it comes out of the two small reservoirs, before it comes into the city.

MR. ALDRICH: It is chlorinated just before it goes into the two mains leading into the city. There is no wading or bathing permitted, and cottages must be at least 600 feet from the reservoir. Experience has shown that if the public is permitted to use the reservoir under strict regulation and if sanitary facilities are provided pollution is lower than if the use of the reservoir is prohibited and people trespass and do not use the sanitary facilities. Our data show that our only pollution, which is very slight, comes from the watershed above the lake, where people camp on the banks of the streams.

MR. ADAMS: What is your *B. coli* count in the lake proper?

MR. ALDRICH: It is very low; it is practically zero, except in periods of high turbidity. It is directly proportional to the turbidity of the water.

THE SECRETARY: I have been begging municipal authorities for years to open reservoirs to fishing. Mr. Aldrich, so far as I know, is the only city fish-culturist in the United States. It is very evident from the things he has told you here today that a great deal depends upon how the man in charge of the fish-cultural work approaches the problem, not of producing more fish but of publicizing good fishing to the people of the municipality who bear the cost of producing that fishing.

In a number of states people are complaining bitterly against the municipal and health authorities because they will not permit fishing, and it is partly their own fault.

# CHANGING THE CLINCH RIVER INTO A TROUT STREAM

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### Abstract

The construction and operation of Norris Dam has changed about 20 miles of the Clinch River from a warm-water to a cold-water stream as the water which is released from the base of the dam usually has a temperature below 50° F. Many of the warm-water fishes were killed by this change. It is hoped this portion of the Clinch River will develop into a trout stream. Rainbow trout were planted in 1936 and a few were taken during the 1937 season.

Quantitative studies of the bottom organisms were made at four localities in this section of the river to discover changes in the warm-water fauna and to determine whether or not a cold-water fauna suitable as a food supply for trout was developing. These studies demonstrated that some of the warm-water forms had disappeared so that only a small residual population was present and that the bottom fauna was not as yet typical of a trout stream. Trichoptera, Ephemeroptera and Odonata were almost lacking. Snails were abundant and constituted 97.21 per cent of the total weight of the bottom organisms found. While all the other organisms constituted 92.98 per cent of the total population they represented only 2.79 per cent of the total weight of the bottom organisms. If a cold-water fauna does not become established in the near future it will be desirable to plant typical trout-stream insects. It is hoped these can be obtained from the trout streams of the Smoky Mountains.

Prior to the erection of Norris Dam, the Clinch River below the present dam site was a warm-water stream typical of the area. It abounded in wide, shallow riffles and had numerous long, deep, quiet pools where large fish were abundant. Several species of pan fish, suckers, bass, and catfish were common and much sought by local anglers. The stream was very rich in molluscs, especially clams, which occurred in large numbers and a variety of species. Other forms of life characteristic of warm-water streams were also present.

Since the construction of Norris Dam and the impoundment of water on March 4, 1936, conditions of existence have been greatly changed. When the gates of the dam were first closed, the water was almost completely shut off. The river became dry for some distance below the dam, except for the water which remained in the deep pools. At the time the water was first released from the dam in June, the bottom fauna in riffle areas had largely been destroyed and the water in the quiet pools had become very warm. The water discharged from the dam in June had a temperature of about 48°F. When this cold water replaced the warm water of the pools, the change in temperature was so great that many fish could not withstand the shock and were killed.

Thus, after June 1936, the character of the Clinch River below Norris Dam was entirely changed. No longer was the water temperature 80°F. or over during the summer. Instead, the water released from the dam at an approximate temperature of 48°F. kept the entire stream cold for many miles down stream. Most of the bottom organisms and fish formerly present in this section moved out or were destroyed.

The Clinch River is now in the early stages of evolution as a cold-water stream. The record of the various stages of development provides a very interesting study. Because the water supply for the river below the dam is cold throughout the year, it is apparent that so far as temperature is concerned, the river now is more suitable for trout than for warm-water species. Therefore, rainbow trout have been introduced and it is hoped that the Clinch River will develop into a trout stream for a distance of at least 20 miles down-stream from Norris Dam. Since most of the warm-water fauna has been destroyed, some time will be required for the development of a cold-water fauna that will serve as a food supply for trout. In order to determine how far this development has progressed since 1936, quantitative counts of the bottom organisms were made in the pools and riffles of four sections of the stream.

The samples were taken from 1 square foot, and the same methods were used as in a former study (Tarzwell, 1938). Section 1 is immediately below the dam where the water is coldest. Brownish scum-like algae are abundant on the stones and bed-rock bottom of this area. Although some boulders and rubble are present in this section, bed-rock bottom predominates. Section 2 is between one-half and three-fourths of a mile below the dam and is an area with gravel rubble riffles and bed rock in the pools. Section 3 which is about 1½ miles below the dam is a shallow riffle area with a clean gravel rubble bottom. Section 4 is 2½ miles below the dam and is a wide, flat area having a bed-rock bottom covered with a thin deposit of fine silt. A few beds of aquatic moss are present. The bottom counts taken in these sections will show the changes in the type of stream fauna more clearly when they are compared with the others it is planned to secure in the near future.

The results of the quantitative analysis of organisms are summarized in Tables 1, 2, and 3. As indicated in Table 1, the average number of organisms in all areas sampled was 406 per square foot. The average number for all the riffles sampled was 567 organisms per square foot, and the average for the pools was 213 organisms per square foot. Quantitative bottom studies made in mountain trout streams of Arizona revealed, on the average, considerably larger numbers of bottom organisms than occur in the Clinch River (Tarzwell, 1938). Averages of 120 quantitative bottom samples from the mountain streams indicated an average riffle population of 1,492 per square

TABLE 1. STANDING POPULATION OF THE BOTTOM FOOD ORGANISMS IN THE CLINCH RIVER, MARCH, 1938

| Location of counts | Number of organisms | | Weight of organisms | | Number of snails | | Number of other organisms | | Weight of snails | | Weight of other organisms | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Per square foot | Per acre | Grams per square foot | Pounds per acre | Per square foot | Per acre | Per square foot | Per acre | Grams per square foot | Pounds per acre | Grams per square foot | Pounds per acre |
| Sect. 1 (Av. of all counts) | 416 | 18,120,960 | 0.26 | 24.9 | .... | .... | 416 | 18,120,960 | ...... | ...... | 0.26 | 24.9 |
| Sect. 1 (Riffles) | 503 | 21,910,680 | 0.33 | 31.9 | .... | .... | 503 | 21,910,680 | ...... | ...... | 0.33 | 31.9 |
| Sect. 1 (Pools) | 243 | 10,585,080 | 0.11 | 10.5 | .... | .... | 243 | 10,585,080 | | .... | 0.11 | 10.5 |
| Sect. 2 (Av. of all counts) | 652 | 28,401,120 | 7.84 | 751.3 | 18 | 784,080 | 634 | 27,617,040 | 7.31 | 700 | 0.53 | 50.8 |
| Sect. 2 (Riffles) | 850 | 37,026,000 | 11.10 | 1,063.7 | 25 | 1,089,000 | 825 | 35,937,000 | 10.44 | 1,000 | 0.67 | 64.2 |
| Sect. 2 (Pools) | 256 | 11,151,360 | 1.33 | 127.5 | 4 | 174,240 | 252 | 10,977,120 | 1.06 | 101 | 0.27 | 25.9 |
| Sect. 3 (Riffles) | 643 | 28,009,080 | 27.26 | 2,612.4 | 73 | 3,179,880 | 570 | 24,829,200 | 26.71 | 2,559 | 0.55 | 52.7 |
| Sect. 4 (Av. of all counts) | 155 | 6,751,800 | 18.66 | 1,788.0 | 47 | 2,047,320 | 108 | 4,704,480 | 18.52 | 1,776 | 0.15 | 14.4 |
| Sect. 4 (Riffles) | 51 | 2,221,560 | 11.45 | 1,097.3 | 31 | 1,350,360 | 20 | 871,200 | 11.37 | 1,090 | 0.07 | 7.2 |
| Sect. 4 (Pools) | 84 | 3,659,040 | 28.39 | 2,720.7 | 70 | 3,049,200 | 14 | 609,840 | 28.38 | 2,718 | 0.02 | 1.9 |
| Sect. 4 (Bed of aq. moss) | 400 | 17,424,000 | 6.43 | 614.0 | 17 | 740,520 | 383 | 16,683,480 | 5.95 | 570 | 0.48 | 43.8 |
| Average for all counts | 406 | 17,685,360 | 11.47 | 1,099.2 | 29 | 1,267,596 | 377 | 16,422,120 | 11.15 | 1,068 | 0.32 | 30.7 |
| Av. for riffles in all secs. | 567 | 24,698,520 | 10.26 | 983.2 | 26 | 1,132,560 | 541 | 23,565,960 | 9.82 | 941 | 0.44 | 42.2 |
| Av. for pools in all sections | 213 | 9,278,280 | 12.93 | 1,238.1 | 32 | 1,393,920 | 181 | 7,884,360 | 12.75 | 1,220 | 0.18 | 17.3 |

foot, while the pool population numbered 805 organisms per square foot. An increase in the number of bottom organisms may occur in the Clinch River below Norris Dam. Although the average number of organisms per unit area in the bottom of the Clinch River below Norris Dam was much smaller than the numbers found in trout streams of the western mountains, the total weight and volume of the Clinch River organisms were much greater than corresponding values for the mountain-stream fauna. This difference was due entirely to the large number of snails present in the Clinch River. The snails comprised 93 to 99 per cent of the total weight of all organisms taken (Table 2) except in Section 1, where no snails occurred.

**TABLE 2. PERCENTAGE ABUNDANCE OF VARIOUS FORMS IN THE STANDING CROP OF BOTTOM ORGANISMS IN THE CLINCH RIVER**

| Location of count | —Percentage of— —total number— | | —Percentage of— —total weight— | |
|---|---|---|---|---|
| | Snails | All other forms | Snails | All other forms |
| Section 1, all counts | 0.00 | 100.00 | 0.00 | 100.00 |
| Section 2, all counts | 2.76 | 97.24 | 93.20 | 6.80 |
| Section 2, riffle | 3.02 | 96.98 | 94.00 | 6.00 |
| Section 2, pool | 1.56 | 98.44 | 79.70 | 20.30 |
| Section 3, riffle | 11.35 | 88.65 | 98.02 | 1.98 |
| Section 4, all counts | 30.32 | 69.68 | 99.33 | 0.67 |
| Section 4, riffle | 60.79 | 39.21 | 99.35 | 0.65 |
| Section 4, pool | 83.34 | 16.66 | 99.95 | 0.05 |
| Section 4, aquatic moss | 4.25 | 95.75 | 92.53 | 4.47 |
| Average for all riffle counts | 4.50 | 95.50 | 95.75 | 4.25 |
| Average for all pool counts | 15.09 | 84.91 | 98.61 | 1.39 |
| Average for all counts | 7.02 | 92.98 | 97.21 | 2.79 |

The standing crop of snails per acre was very large, varying from 101 pounds to 2,718 pounds, with an average of 1,068 pounds per acre (Table 1). As the species of snails present in the Clinch River have very hard shells they cannot with certainty be termed a desirable trout food. The standing crop of bottom organisms other than snails was not large. It varied from 1.9 pounds to 64.2 pounds per acre, and averaged 30.7 pounds per acre. It is to be hoped that the non-molluscan bottom organisms will become more abundant in the future as they provide the best food for trout. Although the latter group of organisms did not weigh as much as the snails, they greatly exceeded the snails in numbers, as indicated by the average number of organisms per acre. The averages of all counts were 1,267,596 snails and 16,422,120 other organisms per acre (Table 1). The densest population was found in the riffles of Section 2 where the calculated population was 1,089,000 snails and 35,937,000 other organisms or a grand total of 37,026,000 organisms per acre (Table 1).

The percentages of the total number and weight of all the organisms constituted by the snails and by all other organisms in the samples are

shown in Table 2. While the snails made up by far the greatest percentage of the total weight of the organisms present, their number represented only a small part of the total population. The snails comprised 7.02 per cent of the total population and 97.21 per cent of the total weight, while the other organisms comprised 92.98 per cent of the population and only 2.79 per cent of the total weight. Snails were relatively more abundant in the pools than in the riffles.

The percentage abundance of the various orders of bottom organisms, excluding snails, is shown in Table 3. The Diptera were of primary importance and the Oligochaeta ranked second. Practically all the Diptera were members of the family Chironomidae. The relative abundance of the various orders of insects in the Clinch River is not typical of most trout streams (Tarzwell 1937, 1938). Usually the mayflies and caddisflies are much more abundant. In western trout streams Trichoptera (caddisflies), Diptera (true flies), and Ephemeroptera (mayflies) were the most important organisms and their relative abundance was in the order in which they are listed. These three orders comprised approximately 86 per cent by number and 83 per cent by volume of all organisms present. A typical trout-stream bottom fauna has not yet been developed in the Clinch River because caddisflies, mayflies, stoneflies and dragonflies were very rare. If these forms do not appear soon, it may be necessary to plant them. Since there are no trout streams nearby, there is little probability of these forms migrating into the Clinch River. Typical cold-water trout stream forms could be secured from the Smoky Mountain area.

**TABLE 3. PERCENTAGE OF TOTAL NUMBER AND PERCENTAGE OF TOTAL VOLUME OF BOTTOM ORGANISMS, EXCEPT SNAILS, CONSTITUTED BY VARIOUS ORDERS OF INVERTEBRATES**

| Order | All counts Percentage of total | | Pools Percentage of total | | Riffles Percentage of total | |
|---|---|---|---|---|---|---|
| | Number | Volume | Number | Volume | Number | Volume |
| Nematoda | 0.44 | 0.13 | 0.40 | ...... | 0.48 | 0.16 |
| [1]Oligochaeta | 13.90 | 6.37 | 16.12 | 11.94 | 13.22 | 5.22 |
| Isopoda | 0.02 | 0.25 | ...... | ...... | 0.04 | 0.31 |
| Ephemeroptera | 0.68 | 1.79 | 0.20 | 1.50 | 0.83 | 1.84 |
| Plecoptera | 0.18 | 1.27 | ...... | ...... | 0.24 | 1.53 |
| Odonota | 0.02 | ...... | 0.10 | ...... | | ...... |
| Coleoptera | 0.79 | 1.27 | 0.30 | ...... | 0.95 | 1.53 |
| Trichoptera | 0.02 | ...... | 0.10 | ...... | ...... | ...... |
| Diptera | 83.90 | 88.92 | 82.78 | 86.56 | 84.25 | 89.41 |

[1]Mostly Tubificidae.

Although certain bottom forms were almost absent, a beginning has been made toward the development of a cold-water fauna in the Clinch River. Diptera which were present in considerable numbers will provide good food, especially for young trout. It is believed that the sup-

ply of fish food has made an encouraging development since the Clinch River has been converted into a cold-water stream. It is hoped that this development of a trout-stream fauna will continue. If it does, a trout stream will have been created from a former warm-water stream. Some catches of rainbow trout have already been made, and there are indications that the Clinch River will furnish trout fishing in addition to a very unusual opportunity for studying the development of a trout stream.

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# FISH-CULTURAL DEVELOPMENTS DURING RECENT YEARS

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ABSTRACT

**Progress in fish-cultural practices has been much slower than it should have been. The trend in trout culture has been to increase the size of fish reared for stocking. Legal-sized fish are now planted in many states. Rearing trout to larger size resulted in many problems such as the need for better and cheaper diets, adequate facilities for holding fish, and the prevention and control of disease. The possibilities in selective breeding are discussed. Progress in bass culture has been more rapid than that in trout. The extensive and intensive methods of rearing bass are described and discussed. The need of experimental work for improvement of fish-cultural practice is urgent.**

It is with considerable trepidation and a full realization that I am treading upon dangerous ground that I have undertaken to discuss briefly some of the more important developments in fish culture in recent years. As used in this connection development is understood to be synonymous with progress although some would deny that there has been much advance in this field. Those of you who attended the Baltimore meeting of the American Fisheries Society may recall that C. F. Culler (1932) told us that in his long experience as a fish-culturist there had been but very little progress and that he considered fish culture to be still in its infancy. A more recent writer (Young, 1938) laments the fact that a modern Rip Van Winkle would find the interior of our hatcheries practically unchanged after thirty years. Had a mere biologist the temerity to make such an assertion he would have received scant consideration but coming from experienced fish-culturists such criticism cannot be easily brushed aside.

Personally, I do not believe the situation is quite as bad as these writers would have us believe but it is all too apparent that progress has been much slower than it should have been.

The early fish-culturist had his problems but no one will deny that, in general, they were much simpler than those that confront his present-day successor. All that was necessary was to strip the eggs from wild fish, incubate them in hatchery troughs and, as soon as the fry were able to feed, turn them loose to shift for themselves. A gullible public was assured that under natural conditions less than 5 per cent of the eggs produced fry while under artifical propagation the situation was reversed.

As the intensity of fishing increased and the supply of fish diminished, the one and only remedy was the construction of more and still more hatcheries. However, even among the pioneer trout-culturists

there were some who began to doubt the efficacy of their methods. They began to speculate on the fact that losses from various environmental hazards were much greater among the fry and small fingerlings than at later stages and that if the young could be held in the hatchery until they reached a length of 2 to 3 inches much of the early loss would be avoided. The rearing to fingerling size eventually became standard practice and, as you all know, is still widely followed.

It is logical to assume that if rearing fish to small fingerlings increases the survival, holding them until they attained an even larger size would reduce the mortality still further. Thus arose the controversy over the relative merits of small and large fingerlings for stocking, a controversy that became so acrimonious that it was necessary to ban it entirely from the meetings of this Society. The next step was to rear trout to legal, or even larger, size before planting. This practice was carried out very successfully by Hayford in New Jersey and has now been adopted to a greater or less extent in many states where the productive capacity of available waters is insufficient to meet the demands of anglers.

It early became evident that in thickly populated regions the supply of eggs from wild fish was no longer equal to the demand and that it would be necessary to maintain a stock of brood fish at the hatchery. This new source of eggs was found to be much more reliable than wild trout, and brood fish are now the mainstay of our eastern hatcheries. It is also apparent that even in the western states it will not be many years before the use of wild eggs will be the exception rather than the rule.

The rearing of brood trout and of larger sizes of young fish brought in its wake problems undreamed of by the early fish-culturists. For the most part these problems fall into three categories: (a) the need of economical and healthful diets to satisfy the voracious appetites of growing fish, (b) maintenance of a suitable environment for the welfare of the fish, and (c) the prevention and control of disease.

The chief development in the evolution of trout diets is the use of dry products. The older fish-culturists were favored with an abundant supply of cheap meat such as the liver of cattle and sheep, and these items soon became standard foods. Prices of these meats have, however, greatly increased, and the fish-culturist of today can no longer afford to rear his charges on these expensive products alone. Consequently, he has been forced to supplement even the cheapest fresh meats with less expensive foods. Plant meals, such as middlings, low grade flour and cottonseed meal, have been used with varying success but at present the tendency is toward animal products such as fish meal, salmon-egg meal, meat meal, and dried milk. While there is still a great deal to be learned about the use of these dry products, relatively few fish-culturists are taking full advantage of the information already available.

With respect to physical equipment there has been but little change.

As the demand for larger fish increased, outdoor pools became a necessity. These pools usually took the form of rectangular raceways, an adaptation of the principle of the hatchery trough to outdoor conditions. In the West we find the troughs supplemented in the hatchery by rectangular tanks which materially increase the carrying capacity of the hatchery for small fingerlings but are not suitable for larger fish. Probably the most notable development in this field in recent years is the increasing use of the round or circular pool. This type of pool, apparently first developed by J. W. Titcomb as a modification of the oval pool used at some Washington hatcheries, is constantly increasing in popularity and is undoubtedly the most efficient type of pool yet devised for rearing fish in a small volume of water.

Considerable progress has been made in the control of fish diseases, but it must be admitted that we still have a long way to go before losses from disease are reduced to reasonable proportions. There has been still less progress in the prevention of disease. Although the general principles involved in checking the spread of an infectious disease are well known, I venture to say that there is hardly a hatchery in the country where really serious attempts are made to prevent the spread of disease, except perhaps sporadically when a serious epidemic threatens.

Treatment with certain chemicals has been found to be quite effective in the control of disease caused by external parasites. This treatment is, of course, only an adaptation of the salt bath that was the one and only recourse of the early trout-culturist when his charges became ill. The salt treatment is very effective with protozoan parasites but is of little value for the control of bacterial infections which can be treated only by means of chemicals with a definite bactericidal action, such as potassium permanganate and copper sulphate.

For obvious reasons, the treatment of diseases caused by internal parasites has been less successful, although the calomel treatment developed by McCay has proved quite effective in ridding trout of the intestinal flagellate, *Octomitus*.

An effective aid in the fight against disease is the development of strains of fish that are more or less immune to the more common hatchery diseases. I doubt if the average fish-culturist realizes the importance of this selectional factor. It apparently explains the well-known fact that hatchery stocks of trout are less subject to disease than wild fish.

There is evidence that this resistance to disease can be increased still further by selective breeding but, so far, few attempts have been made to improve trout by this technique. The principal result of selective breeding, first carried on systematically by Hayford and Embody (1930) has been a remarkable increase in the rate of growth and in egg production. Good results were obtained in two or three generations, and it is surprising to find that so little attention has been paid to the possibilities in this field. Greater vigor, more rapid growth,

increased egg production and hatchability, brighter coloration, and an earlier or later spawning season are among the characters that can be developed by selective breeding.

Turning to the warm-water fishes, it is evident that greater progress has been made in black bass than in trout culture. This difference is largely due to the fact that the artificial propagation of bass is a later development and has been carried on extensively only during the last few years. The evolution of bass culture has closely paralleled that of trout. In the early days few serious attempts were made to rear the young bass beyond the advanced fry or early fingerling stage. It did not take long, however, for bass-culturists to realize that if planting large fingerlings is advisable with trout it should be equally advantageous with bass and other warm-water fishes.

As you all know, two radically different methods of rearing bass fingerlings have been developed in recent years. In the first, or extensive method, the growing fish are entirely dependent on food produced in the pond for their support. This supply of food can be increased materially by proper fertilization which promotes the growth and increase of crustacea and insects. The introduction of forage fish as a supplement to this invertebrate food has yielded varying results. In the second, or intensive method, which has been used with considerable success by Langlois and others (Langlois, 1932), the fingerlings are held in small ponds and fed ground fish or meat. In both methods the advanced fry are usually fed *Daphnia* reared in culture tanks or ponds by the technique developed by Embody.

Both the extensive and intensive methods have their advantages and drawbacks. In the extensive method the fish are reared under more natural conditions, and the cost of providing food is much less. The intensive method permits a much larger number of fish to be produced in a given area but there is the added cost of supplying meat and fish. Furthermore, the crowded, less natural conditions tend to increase the likelihood of infection. Some bass-culturists have successfully combined the two methods; in this way they increase the number and size of fish produced but avoid some of the hazards of the intensive method.

We think that in these later developments in bass culture we have been making progress but how many of you are aware that over forty years ago W. F. Page (1898), superintendent of the federal hatchery at Neosho, Missouri, advocated the artificial feeding of young bass in troughs and small ponds? He also described in detail the use of forage minnows in bass ponds.

Little progress has been made in the improvement of spawning methods except that the three-sided boxes placed around the bass nests by Lydell (1902) have been arranged in series by Langlois (1933) to form stalls along the banks of the ponds. This arrangement permits a material increase in the number of fish that can spawn successfully in a single pond.

Finally, I might point out that in bass culture as in trout culture, there is a growing tendency for each hatchery to rear its own brood stock, rather than rely on wild fish. The advantages of a domesticated brood stock of bass are just as apparent as with trout. It will not be many years before the use of wild fish for breeders will be a thing of the past.

In this survey of developments in modern fish culture I have attempted to outline briefly the more important trends but have made little or no reference to details of hatchery procedure. Also, I have confined the discussion to trout and bass since, after all, with the exception of some commercial species that are reared only to the fry stage, it is toward the maintenance of these fish that most of our fish-cultural activities are directed.

Before I close let us candidly examine the record again. Has there been any marked advance in the art of fish culture during the past twenty-five years? If any of you think that present-day fish culture is essentially different from that practiced by our predecessors I would suggest that you read the Transactions of the early meetings of this Society. There you will find the same problems discussed that are being considered here today, and I venture to predict that the conclusions will not be very different.

Even if the history of the past has been a bit disappointing that of the future need not be. It is up to the members of this Society to see to it that fish culture advances in step with other lines of animal husbandry. If but a very small proportion of the amount now expended on hatchery operations could be devoted to research and experiment and to the training of men in better fish-cultural practices the history of the next twenty-five years would be quite different from that of the past—and it would no longer be necessary to apologize for the shortcomings of our hatcheries.

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## Discussion

Mr. Eugene W. Surber: For the benefit of the administrators and those who have control of funds for the operation of fish hatcheries and experimental stations, I would like to say that although we have many improved methods for the treatment of fish diseases and the feeding of fish, at some places it is impossible to make use of these new ideas simply because fish-cultural establishments are undermanned. I think the problem of personnel in fisheries stations should receive more attention, and probably a study should be made of the amount of personnel required to care for a certain number of fish. That is an important phase of fish culture a study of which I believe would be valuable to us.

Mr. C. O. Hayford: Mr. Chairman, I am not going to discuss the question of selective breeding because that problem has been fully covered in past Transactions, where the figures and the facts on trout have been published, but I would like to talk a few moments on the brood stock of bass raised in the hatcheries. We have been carrying on such work for the last four or five years. At the present time we have our own stock.

We had in Hackettstown, when I left, at least 2,000,000 small bass about an inch long. We have two or three different parasites that have attacked them that we are working on now. We met that same condition last year.

We used the stall system, and each time this system was used we have had trouble with the bass. The more you congregate them, evidently, the more chance there is for disease.

Going back to the time when we put only eight or ten females in a pond and seven or eight males, and hatched out 25,000 small bass fry, we had a great deal better luck in getting large numbers through per acre. We can use the chemicals successfully, but in doing so we kill the *Daphnia* off in the ponds. With one method we have the bass and the parasites, and with the other we have the bass without any food. These are some of the problems on which we are working.

We did bring out something last year that might be of interest in young bass feeding. One of my boys discovered that if he took large *Daphnia magna* alive, mixed them with finely ground sheep's heart and fed the mixture quickly before the *Daphnia* died, the *Daphnia* immediately started swimming when this food was scattered on the water. Of course liver has a movement too, in going down. He had those bass feeding inside of twenty-four hours. We don't anticipate any difficulty in feeding from now on. We can raise *Daphnia* by the millions. That is the easiest thing for us to do. We have limestone water.

We gave our brood bass this year, all of them, a dip in salt water before placing them in the spawning pond. I am not in position to say just what the benefits were, except that we could see that it had no effect on the bass, as in some of the ponds we had exceptionally good luck with our spawning fish.

As Dr. Davis said, probably there isn't much that is new, but I think a lot of the knowledge that we have could be used considerably better than it is.

# TENNESSEE'S FISHERIES PROGRAM

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ABSTRACT

In January, 1938, the Game and Fish Division embarked upon an intensive fisheries program. At the present time, we are able to point to a few specific projects which have been started, and to indicate the probable course of development of the program for the coming year.

Only one project, the compilation of the commercial fisheries statistics for the period, 1931 to June 1, 1938, has been completed. Projects now under way include, stream and lake surveys, pollution studies, creel census, growth-rate studies, commercial fish-yield statistics, and maintenance of stream-improvement structures.

Plans are under way for the development of a commercial fishery under immediate supervision of the State, for legislative revisions to give better protection to game and commercial fishes, and for the publication of a popular illustrated booklet giving the correct common names of the more important species of fish.

Formal application blanks have been devised for the fish-distribution work, and a record is being compiled of past and present stocking activities. Twenty-nine acres of rearing ponds, built by the National Youth Administration and local sportsmen, are being put into operation to supplement the present production of the hatcheries.

The technical fisheries personnel at present includes a fish technician, a survey party of three men (part time), two hatchery superintendents, and two fish-culturists. Special equipment and laboratory facilities have been provided for the fisheries work.

## INTRODUCTION

Noteworthy among the many conservation developments in Tennessee in the last fiscal year has been the initiation of technical wildlife work by the Game and Fish Division of the Tennessee Department of Conservation. In October, 1937, a game technician was employed by this Division, and in January, 1938, a fish technician was hired. These men assist the Director of the Division in the formulation of the State's wildlife and fisheries conservation programs, and also supervise all technical or scientific activities.

A great part of my time as fish technician has been spent in becoming acquainted with the State and its problems. Following this reconnaissance, many projects were undertaken and others planned. These projects are discussed briefly here.

## COMMERCIAL FISHERIES STATISTICS

In order to study the abundance of largemouth bass and other species in Reelfoot Lake, the daily records that have been kept since 1931

at the State Fish Docks were re-examined. The final compilations show the catch from 1931 through 1937 except for one period of eleven months, for which records have been lost. These records form an excellent basis for the determination of the yield per acre, for showing the adequacy or inadequacy of the legal size limits for individual species, and for winning support of legislation designed to end sale of bass.

To date, records of the catch of commercial fishes have been taken only at Reelfoot Lake and during one period of eight months at Open Lake. No reports have been required previously from the professional fishermen on the rivers. Commencing this year, mimeographed monthly report forms have been sent out with the licenses. Inasmuch as we lack authority to make the submission of reports compulsory, we cannot hope for a very good return. We hope that the next legislature will make the report mandatory and that the present efforts to secure statistics will provide some training for the fishermen before the reports are required by law.

### Commercial Fisheries Development

The creation of reservoirs by the Tennessee Valley Authority will give the State of Tennessee jurisdiction over the fisheries of 300,000 acres of water. The opportunity to bring these waters under close regulation and management is unexcelled, but success depends upon two factors, our ability to work out a satisfactory agreement with the Tennessee Valley Authority and legislative action providing much greater regulatory powers.

Of course, there is the challenge to both fisheries agencies to solve the biological problems and to maintain production. If the regulatory powers are granted, it will be possible to maintain the resource on a sustained yield basis at whatever level the reservoirs are capable of producing fish. We estimate that a minimum of 100 pounds of commercial species can be produced on each 3 acres of water. Certainly, this figure should be exceeded on the proposed Gilbertsville reservoir, if it is built. This modest calculation would mean a production of 10,000,000 pounds of fish per annum from the Tennessee River system alone, or a resource worth $1,500,000 each year to the residents of the State. A larger inland commercial fishery would result in improvement of the methods of handling and marketing fish. At present, the waste from spoilage is tremendous and probably results in a loss of 25 per cent of all fish caught, as well as in a reduced price for those actually marketed.

### Stream and Lake Surveys

The stream and lake surveys will follow closely the outline made by Dr. A. S. Hazzard for the Bureau of Fisheries surveys of several years ago. Streams will be examined for pools, current, water sources, and cover. The usual chemical determinations of dissolved oxygen,

carbon dioxide, carbonates and bicarbonates, and pH will be made. Additional determinations will be made of biological oxygen demand and ammonia nitrogen where pollution is involved.

Fish will be considered in more detail than they are in some other surveys. We need information on natural distribution, growth rate, and population density for all our waters. The program will therefore include the taking of many fish collections. Plankton and bottom-fauna studies will be made as thoroughly as facilities permit.

For the purpose of the survey, the State has been divided into watershed districts as follows: Mississippi drainage—four districts—namely, Obion, Forked Deer, Hatchie, and Loosahatchie-Wolf River watersheds; Cumberland drainage—five districts—namely, New River, Obey, Caney Fork, Stones River, and Harpeth watersheds. There remains one additional drainage—parts of the Red and Green River watersheds near the Kentucky line. The Tennessee drainage will be surveyed only if the Tennessee Valley Authority is unable to make the survey by the time we are ready to undertake it. This program will require ten summers' work of one survey party. Work has been started on the survey of the New River watershed.

### Pollution Study

The stream survey will collect data on pollution. We do not believe that the technical problems will be insurmountable as far as the detection of pollution is concerned. Our equipment is sufficiently mobile to permit the investigation of any body of water within twenty-four hours after receipt of a report, although even this lapse of time may be too great.

A difficult aspect of the work lies in the education of the public. There are thousands of signers of petitions who ask that we enforce such pollution laws as are in the statutes, but the communities as a whole, have been so thoroughly "hoodwinked" by the propaganda of the industrialists that when a concern is prosecuted, the cry is raised that we are trying to drive away the source of their income for the sake of a few fish.

Obviously, an industry will not move because it is asked to spend a small amount of money in pollution control, yet a great many concerns threaten to do just that. We believe that water is essentially a resource to be used by the entire public and that no one class of users has an absolute right to it. The rights of each user and the rights of the state must be protected even if industrial profits are reduced a few dollars. Once a community has been made to see the logic of a sound pollution-control program, it will be possible to work out really effective control measures, in cooperation with the companies, or to prosecute those who show no inclination to cooperate.

### Creel Census

The general creel census makes no attempt to record the total pro-

duction per acre, but rather to gather information on the production per man per hour in various waters. The creel-census forms used in Tennessee are a modification of the type used in Michigan, and are bound in books of 100. The form, after removal from the book, measures 4 by 6 inches.

Two procedures are followed in the creel census. In one each conservation officer is provided with forms and is asked to obtain a report from every fisherman he interviews. To obtain further information, we send each chapter of the Tennessee Wildlife Federation (there are 110 chapters and regional offices in Tennessee) one or more booklets for the use of the members. Most of the officers have done excellent work, not only on the creel census, but also in the apprehension of law violators. One warden secured 100 records in about a month's time, and made twelve arrests during the same period. Experience with club census has proven rather discouraging in other states where it has been tried, but we hope that our organization will really make the project a success.

An intensive creel census is being conducted on the Tellico-Citico trout-management area in cooperation with the U. S. Forest Service. Each permittee is handed a census blank with his permit and is given a franked envelope for returning it to the Forest Ranger. Although we do not have 100 per cent returns, the ratio of returns to the total number of permits sold is known. This type of census will also be conducted on waters in state parks and all other waters under the direct supervision of a state agency. Here again, we will know the ratio of returns to the total number of permits sold.

### Stream Improvement

Little improvement work has been undertaken in Tennessee waters up to the present time. Some of the C. C. C. Camps under the supervision of the Forest Service or State Forestry Division have built a few hundred devices. The Game and Fish Division has agreed to maintain these structures. One new project is contemplated for 5 miles of trout stream, and the work will be undertaken by a chapter of the Tennessee Wildlife Federation under the direction of the fish technician.

### Growth Rate Study

Many investigators, the author included, believe that studies of growth rates provide some of the most useful scientific information. The results are of immediate value in intelligent fish management.

We are using scale envelopes similar to those employed elsewhere, and have distributed small lots of them to those conservation officers and sportsmen, who we feel are qualified to take exact data. The survey party will, of course, gather a great amount of scale material.

We have made provision for mounting all our scales on microscope slides, but as yet are not provided with a projection machine. We

hope that Dr. A. R. Cahn, of the Tennessee Valley Authority, will provide such a machine. In return for the use of the apparatus, we could arrange to mount and read scales collected by the T. V. A. investigators.

### Rearing Ponds

The National Youth Administration has built rearing ponds faster than they can be put into operation. As far as is expedient, these ponds will be stocked with a few pairs of brood fish and operated by the regular fish-culturists. We hope to limit spawning sufficiently in the ponds to obtain an approximate production of 2,000 fish per acre. This limited production is expected to result in bass about 5 inches long by late October. We are not at all convinced that artificial propagation is the solution to our warm-water fisheries problems, but if we have to rear fish at all, we would rather rear a few thousand advanced fingerlings than a million fry, even if the fingerling production does not look so impressive on paper.

The improvement in the procedure of applying for fish, and the maintenance of exact records of the actual plants are part of the State's new policy of exercising rigid control over all restocking activities within its jurisdiction. Cooperative agreements are being drawn up to ensure the proper stocking of waters under the control of the U. S. Forest Service.

### Publicity Program

The public is informed of the many new activities of the Division by weekly news releases. One release each month is devoted exclusively to fisheries projects. We have also established a reference and loan library, mostly from donations of papers received from other states and the U. S. Bureau of Fisheries. The library now numbers about 800 titles. Material of special interest is loaned to anyone who will pay postage on the publications sent. An extremely valuable medium for the dissemination of detailed information has been the magazine, "Tennessee Wildlife," published jointly by the Tennessee Wildlife Federation and the Department.

There is a great need for additional public education in the identification of the common game and commercial fishes. Publications issued by the leading tackle manufacturers and sporting magazines, and the booklet on the fishes of Reelfoot Lake (Baker 1937), have all helped to make clear the popular terminology for fish. Nevertheless, there is still an untold amount of confusion, and every fish that cannot be identified appears to be called a "jack." There are at least five fish known as "jacks" in Tennessee at present: wall-eyed pike (*Stizostedion vitreum*) muskellunge (*Esox masquinongy ohioensis*), green pike (*Esox niger*), gizzard shad (*Dorosoma cepedianum*), and yellow bass (*Morone interrupta*). There may be a half dozen others.

The Conservation Department has excellent photographic equipment. A staff photographer is available and all photographic work except printing can be done within the department. We believe that this opportunity for the publication of a popular book on Tennessee fish cannot be neglected. It may be necessary to await the publication of a paper by Drs. Carl Hubbs and A. R. Cahn, on the fish of the Tennessee Valley, in order to be able to follow the correct scientific nomenclature for some of the fish we may wish to include.

Certain improvements are to be expected in fisheries legislation over the entire country as biological data are accumulated. So it is in Tennessee. We believe it will be possible to end the sale of black bass, now legally sold from Reelfoot Lake. In addition, we hope to raise the size limit of fish to a point which will permit a larger percentage of the adults to spawn at least once. Adequate size limits are lacking for some of the less common game fish. Wall-eyed pike (*Stizostedion vitreum*), green pike (*Esox niger*), and muskellunge (*Esox masquinongy ohioensis*) now have a size limit of only 10 inches. Of the important commercial species, sturgeon (*Acipenser sp.*) and spoonbill catfish (*Polyodon spathula*) are unprotected, and catfish may be taken at 10 inches.

## Organization, Equipment and Budget

The increased work of the Division has not necessitated any great re-arrangement of its general organization. A budget of $5,000 has been approved for the technical aspects of the fisheries program. This sum does not include the cost of hatchery operation or the salary of the stenographer, but does include the salary of all other workers and the cost of new equipment. A three-quarter ton panel body truck has been purchased. Microscopes, chemical equipment, camping paraphernalia, nets, and seines, have all been purchased this year. Laboratories have been placed at our disposal at the State Department of Health and at Vanderbilt University.

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# REPORT ON FISH DESTRUCTION IN THE NIAGARA RIVER IN 1937

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### Abstract

The paper reports on the studies made to determine the possible cause or causes of three epidemics of fish mortality which occurred during November and December, 1937, in the vicinity of Buffalo, New York. Samples of water and dead fish were analyzed to determine the lethal agent responsible for the slaughter. Studies of the sources of pollution implicated a small stream dredged to form part of the Buffalo harbor. The sluggish flow through this harbor received the wastes of several large chemical industries and the domestic sewage from a population of some 75,000 persons. This pollution created an extreme septic condition for the major part of the year. Combination of wind velocity and direction, rainfall, and changes in lake level caused sudden discharges of the polluted waters of this small stream into the Niagara River. At such times fish were frequently observed to die. At the time of the three periods of fish mortality some extremely lethal agent seemed to be present that normally must be absent, because the fish mortality was so much greater than had ever been observed previously.

The combination of circumstances of numerous pollution sources, numerous deleterious substances, and the temporary nature of the actual poisoning in the river made it impossible to fix any one effluent as responsible. Investigation disclosed a shortage of available data on the toleration limits of fish, especially under river conditions.

Though the destruction of the fish was regrettable and much needless concern was raised over the health of the Niagara River communities, these three episodes did serve to focus attention on the deplorable conditions existing in the Buffalo harbor. Plans and studies are well under way, by the industries involved, to treat their wastes or to discharge a part of them into the city sewers for treatment. It is hoped that within another year at least 90 per cent of this pollution will be removed and that possible future recurrences of such episodes will be forestalled.[1]

In November and December, 1937, three separate episodes of fish destruction occurred in the Niagara River in the vicinity of Buffalo, New York. These were probably the heaviest sudden mortalities of food and game fish ever recorded in New York State. Ironically enough, in the first two episodes, most of the dead fish appeared immediately below the site of Buffalo's new $4,000,000 sewage treatment plant which was under construction at the time. This fact, coupled with the large numbers of fish washed ashore in the vicinity, occasioned much newspaper and news-reel publicity.

A combination of numerous sources of pollution and possible toxic substances, and the temporary nature of the actual poisoning of the river, made it impossible to fix any one effluent as responsible. This

[1]Since July, 1938, all Buffalo sewage has been treated and approximately 25 per cent of the industrial pollution of the Buffalo River has been removed—Authors.

fact pointedly called attention to the need for more information on the subject of stream pollutants and their toxicity under various stream conditions.

The fish destruction in the Niagara River clearly showed the difficulty of pollution suppression by the present state conservation law. Since research data are insufficient to establish the toleration limits of fish under river conditions, and present analytical methods are not sensitive enough to detect toxic substances in extremely dilute solution, the clause in the New York laws which reads "in quantities injurious to fish life" is of doubtful value.

At the request of and in co-operation with the New York State Conservation Department, the Bird Island Laboratory of the Buffalo Sewer Authority made surveys, collected and analyzed samples, and interviewed observers of each epidemic. Unfortunately, except during the second occurrence, the Laboratory did not learn of the conditions until some time after the onset. Nevertheless, a great amount of data was obtained and the conclusions may be of general interest. From these studies it was possible to trace the source of the pollution causing the fish deaths but the exact lethal agent was not determined.

It is the purpose of this paper to present a summary of the epidemics and the considerations leading to the development of a theory of the source of pollution and method of transmission in the hope that it may be of help in the investigation of fish mortalities which may arise elsewhere. It is not the intent to present detailed data which could have no general bearing on the subject of stream pollution and fish poisoning.

In the first epidemic of dead fish on November 14, the larger fish died by the thousands and minnows and fingerlings by the millions. Of the larger species, gizzard shad (*Dorosoma cepedianum*), locally called moon-eyes, suffered the most, but there were thousands of pan fish including scores of wall-eyed (yellow) and blue pike, rock bass and perch. There were also some pickerel, muskellunge and carp killed. The heaviest mortality was among the minnows, particularly the lake shiner (*Notropis atherinoides*).

The first indication of poisoning was the rising of fish to the surface. These specimens were reported to be gasping for air, leading many observers to assume that they were dying of suffocation. Within a short period after rising to the surface, the fish would turn "belly-up" and after struggling in this position for a time would die. If removed, prior to death, from the polluted water to fresh water, the fish would revive. This revival generally occurred within a few minutes, though it required forty-eight hours to completely revive one pickerel in the laboratory. It was reported that the tern would not dive for minnows in the polluted zone, but gulls were observed eating dead minnows.

In the bays along the shore dead minnows were knee deep, 25 to 30 feet off shore. When the wind subsided and the water level receded, the shore was piled with a strip of minnows and other fish, approximately 4 feet wide, 3 inches deep and 3 to 4 miles long. Along one strip of shore approximately a mile in length, it was estimated there were 125,000,000 minnows, including possibly 5 per cent of small game fish. This estimate was based on the actual count of the number of minnows held in a liter container. Since many of the minnows that died did not wash ashore, and since the total shore line covered was probably 4 miles long, it was calculated that a kill of 500,000,000 minnows would be a conservative estimate. On the basis of the determined weight of 1½ pounds for 600 minnows, it was computed that approximately 600 tons of minnows died.

During the morning of November 27, a recurrence of fish deaths was observed. Fewer of the larger fish were killed on this date, and practically no minnows. In this epidemic, samples were collected during the time the fish were observed to be dying. As in the first occurrence the lethal effects were noted for only a few miles below Buffalo.

On December 18, in the late afternoon, fish began to die in large numbers for a third time a short distance below the outlet of Lake Erie. By the next morning fish were reported to be dying on the surface at Niagara Falls where power-plant intakes were becoming clogged with the dead and dying fish. Samples of water were obtained from the river above the Falls during the height of the mortality.

Some persons who ate fish that had been picked up as they washed ashore reported intestinal disturbances. The City of Buffalo Health Department issued warnings against eating such fish after spectroscopic traces of cyanides in the fish were reported by the city toxicologist.

Without allowing time for sane considerations of analyses or of the various factors involved, the general public raised a great hue and cry against industries; sales at local fish markets dropped off markedly, and considerable concern was voiced over the purity of the drinking water from Buffalo to Niagara Falls. The inevitable crop of rumors, opinions and tips as to the cause of the fish poisoning was brought to the attention of the Laboratory. It is these rumors and garbled reports of laboratory findings which give rise to a hysteria that must, if possible, be controlled.

In studying cases of fish poisoning, the observer must consider first the possible sources of pollution. Then the various theories presented may be examined in light of the facts developed. In this particular instance, an excellent knowledge of the pollution background was available through two years of study of the sewers and streams in and about Buffalo. The locations of sampling stations and sources of pol-

lution in 1937 are shown on the accompanying map. From this map it may be seen that sources of pollution in the Niagara River existed to the south of the city in industrial wastes, in the Buffalo River, in three main sewers of Buffalo, and in several industries and cities to the north of Buffalo. The wastes of steel industries to the south of the city entered the lake through the outer harbor and were greatly diluted. The Buffalo River is a small stream dredged to form a part of the local harbor. It discharges into the lake through the north entrance to the harbor, nearly 2 miles above the beginning of the Niagara River. The Buffalo River normally has a small flow and at the times of the fish mortality it received about 15 per cent of the city sewage and the waste from six large industries. The flow time through the dredged portion was rather long and the condition of the stream was generally septic. A short distance below the Peace Bridge, which marks the end of Lake Erie and the beginning of the Niagara River, approximately half of the sewage of the city entered the river. Below this sewer, two other large sewers discharged (one indirectly, one directly) into the Niagara River. Industries and towns to the north of Buffalo were not implicated directly in these episodes since the fish died above these outlets.

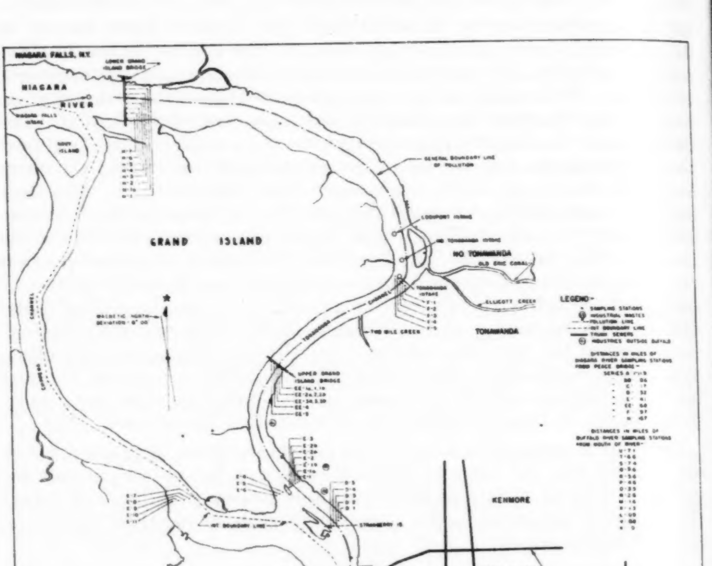
Now that a general picture of the possible sources of pollution has been formulated, the list of suggested causes of fish poisoning may be examined with such data as were available to prove or disprove them. The following list includes the suggestions made in the three instances of heavy fish mortality:

1. The first cause suggested was dynamiting in connection with the construction of the sewage treatment plant and intercepting sewers. All three of the episodes of mortality occurred on week-ends when construction was not in progress. The symptoms of the fish deaths were not typical of blasting. Furthermore, blasting in the canal during the summer of 1937 and blasting in the sewers during 1936 and 1937 caused no fish deaths.

2. It was reported that several barges of sulphur had sunk in Lake Erie. This gave rise to the theory in some quarters that acids formed from the sulphur had killed the fish. Obviously, this theory was incorrect because sulphur is practically insoluble and if any acid were formed it would be neutralized by the alkalinity of the lake water. Furthermore, no dead fish were reported in the lake between Buffalo and the location of the sulphur barges, and no acid condition was ever found in the river water.

3. It was suggested that high voltage electric cables at the sewage treatment plant construction site had been placed in the Niagara River by workmen to kill fish. The absurdity of this theory was evident when one considered the facts that fish died miles below the construction site but that none died within 200 yards out in midstream opposite the site.

4. Many persons, particularly those living in towns below Buffalo,


NIAGARA FALLS, N.Y.
NIAGARA
RIVER
GRAND ISLAND
NO TONAWANDA
TONAWANDA
LEGEND
KENMORE
BUFFALO SEWER AUTHORITY
LOCATION MAP
OF
SAMPLING STATIONS
STREAM POLLUTION STUDIES
1936-38
LAKE ERIE
BIRD ISLAND LABORATORY

believed that the fish were killed by the sewage and waste discharged by the trunk sewer which emptied into the Niagara River immediately south of the treatment plant site. This sewer passed under the canal (see map) and discharged into the river at a point where the velocity of the current is 6 to 7 miles per hour. Dead fish were observed in the canal, and in the river to the south and above the sewer outlet. Therefore, this sewer could not have been implicated as it was impossible for the sewage to enter the canal or to move upstream toward the lake. Furthermore, analysis of the sewage during the second epidemic showed no phenol, copper or iron content, whereas these substances were found in the river water.

5. Another suggested cause of mortality was acid wastes from steel plants to the south of the city. No evidence of acid was ever found as the pH was consistently above 7.2.

6. One insistent rumor was to the effect that a wood alcohol plant had dumped alcohol and waste products into the river. This plant was found to have been shut down for several years.

7. Fertilizer, insecticide and flour-bleaching chemicals were suspected of having entered the sewers or the Buffalo River. No evidence could be found to support this contention.

8. All other theories involved the Buffalo River in some manner, and with these the authors agreed at least as to source though not necessarily as to cause.

On the basis of twenty months of regular sampling and analyses of the water of this stream, the authors developed an explanation of the mortalities. In the development of this explanation the following items were considered:

1. The Buffalo River, within the city limits, is a dredged basin of some 5.6 miles in length and with a volume of approximately 165,000,000 cubic feet. It has a normal flow in the summer of 50 to 60 cubic feet per second, and in the fall of 100 to 200 cubic feet per second, and therefore a detention period in summer of thirty to thirty-five days and in the fall of approximately ten to twenty days.

2. The actual discharge of this dredged stream is affected by the lake level. The flow reverses when strong prevailing southwest winds are blowing. Under these conditions, diffusion of the lake water diluted the waste at the outlet of the Buffalo River. At the same time concentrated wastes were backed up in the upper end of this river.

3. On the basis of organic matter and biochemical oxygen demand, it was determined that the composition of the waste in the river was approximately 70 per cent industrial and 30 per cent sewage. On a biochemical oxygen demand basis, the pollution input of this stream

was computed to be equivalent to that obtained from approximately 250,000 persons.

4. The industrial wastes discharged into the stream contained acids, iron compounds, nitrogenous organic chemical wastes, phenolic bodies, organic and inorganic sulphur compounds, oil wastes, coke-oven and ammonia-still wastes, thiocyanates, possibly cyanides and many other organic chemicals.

5. During the warm season, from May to November, no dissolved oxygen was present in the stream. Septic conditions were prevalent, with much hydrogen sulphide and colloidal ferrous sulphide in evidence until cold weather and higher flows occurred in late November. This was the condition on November 14 at the time of the first epidemic.

6. Wastes are dumped along the shores and may have been leached into the stream. Lime waste from acetylene plants have been so dumped.

7. Spectroscopic traces of cyanide were found in the blood of the dead fish. Dr. M. M. Ellis, in charge Interior Fisheries Investigations, U. S. Bureau of Fisheries, advised us that spectroscopic tests for cyanide in fish blood are not subject to the same interpretation as in human blood. The presence of oxyhemoglobin would seem to preclude the possibility that the fish died from lack of oxygen.

8. Although there was practically no oxygen in the Buffalo River at the time of the first epidemic (no samples of the Niagara River were obtained at this time), none of the samples collected indicated that the Niagara River was devoid of oxygen even in the polluted area where 5 p.p.m. of dissolved oxygen was the lowest found.

9. Autopsies on the fish showed gill capillary constriction and evidence of toxemia. Analyses of the viscera of different fish were made in three different laboratories. One laboratory reported traces of cyanide and phenol, but the other two found no evidences of cyanide. Phenol is produced by decomposition of the fish and its presence in the body, therefore, is not a positive test of pollution.

10. Normally there are no evidences of phenol in the Niagara River, but during the three epidemics of fish mortality phenols were found in this river, the maximum concentration being 120 parts per billion. Normally the phenols in the Buffalo River were destroyed by bacterial action during the slow movement of the stream, but with a sudden flushing condition they would be swept into the Niagara River before decomposition. This point was important as it indicated that a sudden flushing of the dredged basin of the Buffalo River had occurred during the three epidemics.

11. A study of wind velocities and direction, lake level rise and fall, rainfall and flow time of the Buffalo River indicated that at the time of each mortality the combination of some, if not all, of these factors was propitious for a sudden discharge of the pent-up waste

waters of the Buffalo River into the Niagara River. Under these conditions, the normal dilution of the wastes with Lake Erie water would not occur. The fact that at the time of the second mortality there was no rain ruled out the possibility that the poison was acetylene or other chemicals leached from wastes dumped along the shores of the Buffalo River.

12. The suggestion was made to the authors that cyanide was being dumped surreptitiously on week-ends, either by some plant undergoing fumigation or by a large chemical plant that was curtailing operations at the time. This suggestion was obviously erroneous for two reasons. First, the flow time through the dredged basin of the Buffalo River was 2.8, 3.5 and 4.0 days respectively at the time of the first, second, and third episodes of fish mortality. Prior to each episode, the flow time was greater than normal. It is difficult to believe that any "dumper" would have known this and calculated accordingly in order to get his waste to the Niagara River on Saturday or Sunday. Secondly, calculations indicated that to maintain a concentration of 0.1 p.p.m of cyanide in the polluted zone of the Niagara River for five to six hours would have required more than 3 tons of sodium cyanide. It is doubtful if any of the plants on the Buffalo River would intentionally or unintentionally dispose of that quantity of sodium cyanide. No permits had been issued by the Board of Health for the use of cyanide in fumigating.

13. Testimony of river men indicated that in previous years a combination of rain and northeast winds had usually been followed by the death of some fishes and minnows in the Niagara River, but never had the destruction been so great. If this was true, it was indicated that some definite lethal agent of unknown source must have been present on the three occasions of heavy mortality. That lethal agent was not always present since similar destruction of fish did not occur at all times when the Buffalo River was flushed out.

14. Laboratory experiments on fish collected from the Niagara River showed that 10 p.p.m. of cyanide were necessary to kill carp in $1\frac{1}{2}$ hours and 10 p.p.m. of phenol did not kill carp in six hours. Carp died in the river in less than two hours. Samples of river water that contained only 79 parts per billion of phenol killed minnows in thirty minutes but did not kill goldfish.

Dr. John R. Greeley, Ichthyologist of the New York State Department of Conservation, suggested that under the conditions of swimming against a strong current in cold water a smaller dose of a combination of these agents or others might prove too much for the physiological processes of the fish. Under laboratory conditions where no distinct physical exertion was necessary on the part of the fish, higher concentrations of chemical poisons would be required to demonstrate any lethal effect.

## Summary

The investigations of three epidemics of fish mortality in the Niagara River in November and December, 1937, resulted in the following conclusions:

1. These occurrences were the most spectacular and most destructive instances of fish mortality ever recorded in New York State.

2. The temporary nature of the river poisoning, the many possible sources of pollution, and the numerous deleterious substances known to be present in the water prevented the determination of the responsibility of a particular effluent or definite lethal agent. The concentration of the particular toxic substance or combination of chemical poisons of unknown compositions, was obviously extremely dilute but sufficient to cause toxemia in the fish in a very short time under the conditions of low temperature and stream currents.

3. In the three epidemics described, the source of the poisonous wastes was a small, highly polluted stream flowing through the city and which, on the dates in question, discharged its load of polluted water suddenly and more rapidly than usual due to a combination of rains, wind, and change in lake levels. Under these conditions there was less dilution of these wastes by lake water.

4. These poisons may have been the result of chemical and biochemical action on the normal industrial wastes and domestic sewage discharged into the stream. On the other hand, the pollutants may have been specific discharges of toxic materials not ordinarily received by the stream, or they may have been produced by biochemical action on substances not ordinarily discharged.

5. Regardless of the widespread destruction of fish in the water, the substances causing the fish deaths were present in quantities too minute to cause any harmful effect on persons drinking the water, particularly after filtration and chlorination.

6. The ordinary sanitary chemical analyses were not sensitive enough or were not adequate to detect substances which may be termed unusual or poisonous in their action toward aquatic life. Only the phenol test, which is not normally made as a part of a sanitary analysis, is sufficiently sensitive for this type of study.

7. The episodes illustrated clearly the difficulties of determining "injurious quantities," for the purpose of suppressing or preventing pollution, and also emphasized the fact that there is a shortage of available data on toleration limits of fish especially under stream conditions.

8. These investigations showed that in streams of large and rapid flow it is essential that samples collected shall be representative of the streams at the particular time of toxic condition. For this reason, sportsmen and other observers should if possible collect samples of the water when they first observe that fish are being poisoned. Such

samples when delivered to the conservation department representatives will prove of invaluable aid in determining the cause of fish mortalities.

9. Although the destruction of the fish was regrettable and much needless concern was raised over the health of the Niagara Frontier communities, these three episodes of fish mortality did serve to focus attention on the deplorable condition existing locally. These happenings brought together the interests of the state departments of health and conservation in the co-operative efforts of the industries and the Buffalo Sewer Authority to solve the problem of the industrial pollution of this stream. Plans and studies are well under way by the industries involved to treat their wastes or discharge part of them into the city sewers, and it is hoped that within another year at least 90 per cent of the pollution will be removed from this cesspool that serves as part of the Buffalo harbor.

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# MOVEMENT OF FISH IN STREAMS

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Abstract

**This report is a continuation of a study conducted during the spring and summer of 1936 (Bangham, 1937) and includes in addition to the area covered in the earlier investigation, two other portions of stream each 1 mile in length. As in 1936 the larger fish were tagged, measured and then released. From June 15 to September 17, 1937, 11.7 per cent of 487 tagged fish were recaptured. No fish tagged the previous year were caught.**

Data on the migration of stream fishes in Ohio are very scanty. The results of the preliminary study of 1936 (Bangham, 1937) led the Department of Conservation to provide funds for a more intensive study of the movement of native stream fish in 1937.

Periodic visits were made during the summer of 1937 to three selected areas. On each occasion the same mile of stream was seined. The three stream sections were all in Wayne County, Ohio, in headwater streams of the Muskingum River system. Station No. 1 was located on Sugar Creek, not far from the village of Smithville. The stream was rather narrow; much of it coursed through open meadows. In places the water was ponded for distances of 100 to 200 feet with short riffles at both ends. There was one pool too deep for seining. The banks were not greatly undercut but along portions of the stream they were overhung by bushes and small trees. Some pools contained large stones which interfered with the seining operations, but offered good hiding places for fish. This same area was used in the tagging work of 1936.

Station No. 2 was on Salt Creek near the village of Fredericksburg. The stream was somewhat wider here than at Station No. 1, and contained longer riffles and many flat limestone rocks, but not as many deep pools. The stream occupied a deeper valley and more large trees bordered it. The banks were undercut in many places. Under the willow trees especially, there were excellent hiding places for fish.

Station No. 3 was on Sugar Creek but differed limnologically from Station No. 1. It was from 10 to 12 miles by water below Station No. 1, and 2 miles below the village of Dalton. The dredging of portions of the area ten or eleven years previously left long stretches of water 2 to 3 feet deep. In places the stream was 30 feet or more in

width. Five or six riffles were present in the mile but there were few stones and not as many hiding places for fish as in Salt Creek. Small willows bordered about one-half of the mile of stream and larger trees were located some distance from the banks over the remainder of the area.

Each time the mile area at a station was seined the larger fish were tagged and measured. At the same time scale samples were taken for age determination. Limnological data, consisting of chemical tests and turbidity, depth and temperature readings, were also obtained. Samples of minnows and crayfish were secured by a 150-foot haul of a 20-foot minnow seine. These collections were taken to the laboratory for identification, measurement and food and parasite studies.

The tags used for marking the fish were the familiar "strap" or "clip" tag made of aluminum. On one side of the tag is the word "Ohio," and on the other a serial number. The tags were attached with specially designed pliers. Prior to this study, tags in Ohio had been most often clamped over the gill covers. As reported in the 1936 survey (Bangham, 1937) fish marked in this manner sometimes lost their tags. In the present study, where the condition of fish carrying their tags could be determined at frequent intervals, fish with the gill-cover tag often had C-shaped openings where the tag had dropped out. In 1937 the jaw-tag method of marking fish, described by Shetter (1936), was tried with good results. This method was used on smallmouth bass, rock bass, green sunfish and black bullheads. Jaw tags were not lost and the recaptured fish were in better condition than many of those with tags on the gill covers. The suckers, which had to be tagged on the gill covers, were frequently recaptured after they had lost their tags or when they were about to lose them. The records of recapture of suckers are low (Tables 1 to 3) because of this loss of markers.

In addition to the periodic trips to the three selected stations, the other streams of the county were visited in order to study the fish populations. Some fish were tagged in these streams but this report includes only records from the three areas already described. Fifty species of fish were taken in the county but only twelve species were obtained in any numbers in the 1-inch-mesh bag seine, which measured 6 by 14 feet.

Fifteen seinings were made at Station No. 1. Smallmouth bass and rock bass were not only taken in almost equal numbers but the numbers tagged and recaptured were identical (Table 1). The percentage of recaptures of hog suckers and common suckers was low. Black bullheads were taken on each trip but they were found in larger numbers when the water was muddy. The percentage of recaptures was higher in 1936 than in 1937. The higher water of 1937 may have allowed more movement of fishes in the stream. In 1936 the majority of seining trips was made in May and June; in 1937 our visits to this location started the last of May. No fish tagged in 1936 were re-

captured in 1937. A common sucker tagged September 16, 1936, was caught by a line fisherman April 5, 1937, some 10 miles below Station No. 1.

TABLE 1. SUMMARY OF WEEKLY OBSERVATIONS AT SUGAR CREEK, NEAR SMITHVILLE, OHIO (STATION NO. 1)

| Species listed in order of abundance | Number of fish caught | Number tagged | Number of tagged fish recaptured | Percentage of tagged fish recaptured |
|---|---|---|---|---|
| 1. Common shiner, *Notropis cornutus* | 238 | 0 | ---- | ---- |
| 2. Smallmouth bass, *Micropterus dolomieu* | 134 | 61 | 12 | 19.6 |
| 3. Rock bass, *Ambloplites rupestris* | 130 | 61 | 12 | 19.6 |
| 4. Common sucker, *Catostomus commersonnii* | 118 | 50 | 3 | 6.0 |
| 5. Hog sucker, *Hypentelium nigricans* | 78 | 32 | 3 | 9.4 |
| 6. Black bullhead, *Ameiurus melas* | 46 | 20 | 2 | 10.0 |
| 7. Green sunfish, *Apomotis cyanellus* | 37 | 5 | 1 | 20.0 |
| 8. Red-horse sucker, *Moxostoma aureoleum* | 21 | 8 | 0 | 0.0 |
| 9. Chub, *Semotilus atromaculatus* | 9 | 0 | -- | ---- |
| 10. Quillback, *Carpiodes cyprinus* | 2 | 1 | 0 | 0.0 |
| 11. White crappie, *Pomoxis annularis* | 2 | 0 | -- | ---- |

The smallmouth bass was the dominant species in Salt Creek (Table 2). Twenty-seven per cent of those tagged were from 5 to 7 inches in length. Rough fish made up the majority of the remaining species. Ten trips were made to Salt Creek.

TABLE 2. SUMMARY OF WEEKLY OBSERVATIONS AT SALT CREEK, NEAR FREDERICKSBURG, OHIO (STATION NO. 2)

| Species listed in order of abundance | Number of fish caught | Number tagged | Number of tagged fish recaptured | Percentage of tagged fish recaptured |
|---|---|---|---|---|
| 1. Smallmouth bass | 194 | 77 | 13 | 17.0 |
| 2. Chub | 83 | 1 | 0 | 0.0 |
| 3. Hog sucker | 67 | 26 | 3 | 11.5 |
| 4. Common shiner | 59 | 0 | -- | ---- |
| 5. Common sucker | 50 | 27 | 3 | 11.1 |
| 6. Rock bass | 15 | 13 | 4 | 30.7 |
| 7. Green sunfish | 3 | 1 | 0 | 0.0 |

Red-horse suckers were the most abundant species at Station No. 3 in Sugar Creek (Table 3). In one of the nine trips no fish were taken because of high water. None of eight tagged common suckers was recaptured and only one of fifty-three red-horse suckers was taken again. Our small seine and the width of the stream made the capture of fish more difficult here than at the other two stations.

TABLE 3. SUMMARY OF WEEKLY OBSERVATIONS AT SUGAR CREEK, NEAR DALTON, OHIO (STATION NO. 3)

| Species listed in order of abundance | Number of fish caught | Number tagged | Number of tagged fish recaptured | Percentage of tagged fish recaptured |
|---|---|---|---|---|
| 1. Red-horse sucker | 83 | 53 | 1 | 1.8 |
| 2. Common shiner | 64 | 0 | -- | ---- |
| 3. Hog sucker | 37 | 8 | 2 | 25.0 |
| 4. Smallmouth bass | 33 | 19 | 6 | 31.5 |
| 5. Common sucker | 27 | 8 | 0 | 0.0 |
| 6. Chub | 26 | 0 | -- | ---- |
| 7. Rock bass | 16 | 12 | 2 | 16.6 |
| 8. Carp, *Cyprinus carpio* | 16 | 1 | 0 | 0.0 |
| 9. Green sunfish | 5 | 0 | -- | ---- |
| 10. Black bullhead | 4 | 3 | 0 | 0.0 |
| 11. Mud pickerel, *Esox vermiculatus* | 3 | 0 | -- | ---- |
| 12. White crappie | 2 | 0 | -- | ---- |

At each of the stations more recaptures came within two weeks after the fish were tagged than in later seining trips, but a few fish tagged early in the season were recovered late in the summer in the same mile of stream. As in 1936, the common shiners made up a larger percentage of the catch early in the season, especially at Station No. 1. The percentage of smallmouth bass in the total catch showed considerable variation from week to week. At Station No. 1 (Table 4) the smallmouth bass made up 2.4 to 31.6 per cent of the catch. The percentage of rock bass in the catch from week to week showed almost as large a variation as that of smallmouth bass. The largest difference was found at Station No. 1, where the range was from 0.0 to 31.4 per cent of the total number. The percentage of rock bass was higher in the latter part of the season. The number of common suckers varied from week to week but at Station No. 1 the range was less than for the other fish.

The smallmouth bass made up a larger percentage of the catch at Station No. 2 early in the period (Table 5). Later in the season few larger smallmouth bass were captured. Except for the first visit to Station No. 2 the proportion of chubs caught did not show much variation. Common shiners made up a smaller proportion of the fish at Station No. 2 than at the other locations. Common suckers comprised about 10 per cent of the catch; the range was from 2.5 to 15.8 per cent of the total. Rock bass never made up a large percentage of the fish caught, although many of our largest specimens were recorded from Salt Creek.

At Station No. 3 the red-horse suckers made up from 6.6 to 39.5 per cent of the fish (Table 6). The common shiners were next in relative abundance and, as at Station No. 1, were found in greater numbers on the first trips, although they comprised about one-fourth of the fish on the last two visits. Common suckers never represented more than one-fourth of the total catch. Twice they were absent from

TABLE 4. THE RELATIVE ABUNDANCE OF FIVE SPECIES EXPRESSED AS PERCENTAGES OF THE TOTAL CATCH AT THE TIME OF EACH SEINING TRIP TO STATION NO. 1 IN 1937

| Species | Date | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | May 29 | June 4 | June 11 | June 18 | June 25 | July 2 | July 9 | July 16 | July 24 | July 30 | August 6 | August 12 | August 19 | August 26 | September 17 |
| Common shiner | 68.2 | 22.6 | 42.1 | 56.5 | 40.0 | 25.0 | 21.1 | 24.2 | 21.6 | 20.0 | 4.1 | 12.6 | 9.5 | 21.1 | 16.2 |
| Smallmouth bass | 8.0 | 9.1 | 31.6 | 15.4 | 13.3 | 19.0 | 11.5 | 30.0 | 30.0 | 25.7 | 4.1 | 18.3 | 2.4 | 9.6 | 3.5 |
| Rock bass | 5.7 | 10.0 | 4.0 | 6.6 | 4.4 | 0.0 | 30.7 | 10.0 | 19.1 | 20.0 | 29.1 | 15.5 | 26.2 | 21.9 | 31.4 |
| Common sucker | 16.0 | 20.8 | 10.5 | 2.2 | 15.5 | 22.0 | 19.2 | 11.4 | 5.4 | 8.8 | 14.6 | 9.8 | 7.1 | 21.9 | 25.5 |
| Black bullhead | 0.0 | 4.1 | 2.6 | 0.0 | 4.4 | 3.2 | 0.0 | 20.0 | 13.5 | 5.7 | 12.5 | 11.2 | 11.9 | 5.7 | 1.1 |

**TABLE 5. THE RELATIVE ABUNDANCE OF SIX SPECIES EXPRESSED AS PERCENTAGES OF TOTAL CATCH AT THE TIME OF EACH SEINING TRIP TO STATION NO. 2 IN 1937**

| Species | Date | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | June 29 | July 7 | July 14 | July 20 | July 29 | August 4 | August 11 | August 18 | August 25 | September 16 |
| Smallmouth bass | 40.3 | 50.0 | 57.7 | 40.3 | 39.3 | 39.4 | 37.9 | 22.5 | 25.0 | 31.4 |
| Chub | 0.0 | 24.2 | 17.3 | 22.8 | 13.1 | 16.9 | 20.7 | 15.0 | 19.4 | 20.0 |
| Hog sucker | 12.4 | 6.4 | 1.9 | 10.5 | 21.3 | 14.0 | 13.7 | 20.0 | 22.2 | 11.4 |
| Common shiner | 29.8 | 12.8 | 9.6 | 7.0 | 6.5 | 12.6 | 6.9 | 20.0 | 13.9 | 22.8 |
| Common sucker | 15.8 | 4.8 | 13.4 | 14.0 | 13.1 | 9.8 | 13.7 | 2.5 | 8.3 | 11.4 |
| Rock bass | 1.7 | 4.8 | 0.0 | 3.5 | 6.5 | 2.8 | 3.4 | 5.0 | 8.3 | 2.8 |

the catch. Hog suckers made up about 10 per cent of the catch and varied less than the other species. A greater percentage of large smallmouth bass was taken at Station No. 3 than at the other stations. The highest percentage was recorded on July 3, when smallmouth bass constituted 22.6 per cent of the fish seined. Rock bass were absent from the catches on two trips, and carp on three trips (Table 6).

**TABLE 6. THE RELATIVE ABUNDANCE OF EIGHT SPECIES EXPRESSED AS PERCENTAGES OF THE TOTAL CATCH AT THE TIME OF EACH SEINING TRIP TO STATION NO. 3 IN 1937**

| Species | Date | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | June 19 | July 3 | July 22 | July 31 | August 7 | August 13 | August 20 | August 27 |
| Red-horse sucker | 19.2 | 29.0 | 36.9 | 24.2 | 6.6 | 39.5 | 20.5 | 14.6 |
| Common sucker | 5.7 | 0.0 | 12.3 | 0.0 | 23.3 | 7.0 | 2.5 | 14.6 |
| Hog sucker | 9.6 | 6.4 | 12.3 | 15.1 | 10.0 | 18.6 | 10.2 | 7.1 |
| Smallmouth bass | 13.4 | 22.6 | 10.7 | 18.1 | 10.0 | 2.3 | 2.5 | 3.5 |
| Common shiner | 46.1 | 35.5 | 9.2 | 21.2 | 6.6 | 13.9 | 25.6 | 21.4 |
| Chub | 0.0 | 0.0 | 7.7 | 3.0 | 6.6 | 11.6 | 10.2 | 32.1 |
| Rock bass | 5.7 | 0.0 | 4.6 | 3.0 | 13.3 | 0.0 | 5.1 | 3.5 |
| Carp | 0.0 | 0.0 | 4.6 | 12.1 | 10.0 | 4.6 | 10.2 | 0.0 |

Native stream fish seem to be acclimated to their habitat and do not move as far as introduced fish. Wickliff (1938) reported that the tag returns of marked fish planted in Ohio streams show a decided downstream movement. As Station No. 2 was below Station No. 1, some fish marked at Station No. 1 should have been recovered at Station No. 2 if the fish did move downstream very far. No marked fish were taken by us except near the station where the tagging was done.

Reports from fishermen have been meager, but 1.3 per cent of our tagged fish have been caught and reported by line fishermen. All of these recoveries were obtained within 10 miles of our stations and most of those reported were recovered but 1 or 2 miles from the point of tagging.

We have found as a result of the two seasons' work that a much larger percentage of recaptures can be made in these smaller streams by periodic seining trips after tagging than by returns reported by fishermen. The data on the distribution of species show considerable variation in the species composition of the fish population of a given area from week to week. We do not know the fate of fish tagged in 1936.

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## Discussion

Mr. E. L. Wickliff: Dr. Bangham stated the percentage of returns has been very low. We seldom received more than 5 per cent of returns on the fish tags. Recently a paper in Columbus, Ohio, has offered prizes of more than $4,000 for returns of tagged fish taken within 50 miles of Columbus. The Division of Conservation tags the fish, and releases them; the newspaper publishes the prize-winning tag numbers and publishes where the fish are released, and in one instance within two weeks from the time the fish were put out we had 10 per cent returns, whereas in our work we never had 10 per cent returns. Therefore, it looks like the necessary thing to do is to offer prizes and get good newspaper publicity. There is one fish that is worth $400 if you can catch him.

Acting Chairman Foster: That is very interesting, indeed. I am sure we all appreciate the great benefit that may be derived by the accurate information from returned tagged fish. Of course, on the Pacific Coast we are very much interested in the tagging of salmon and halibut and other fishes, and a very great deal can be learned about their life history with beneficial results in the compilation of regulations. I think that in all probability in some of our inland streams we will follow that tagging program to a far greater extent than has been done heretofore.

# PARASITES OF CENTRARCHIDAE FROM SOUTHERN FLORIDA

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Abstract

The paper reports a preliminary study of the parasites of eight species of fish of the family Centrarchidae. Centrarchids were numerous and widely distributed in the waters from which specimens were secured for examination. These fish along with the predaceous gars made up a dominant group in most areas visited. Of the 516 Centrarchidae examined, 513 or 99.4 per cent were parasitized. This percentage of infestation is higher than that found in the same species from northern waters. Fewer species of parasites were found in the Florida centrarchids. Larval encysted nematodes, strigeid flukes and gill flukes made up a majority of the parasites. Cestodes were taken much less frequently than from northern fish. The parasites of the following species are discussed: largemouth black bass, *Huro salmoides;* warmouth bass, *Chaenobryttus gulosus;* bluegill, *Helioperca macrochira;* black crappie, *Pomoxis sparoides;* blue-spotted sunfish, *Enneacanthus gloriosus;* stump-knocker, *Eupomotis microlophus;* black-spotted sunfish, *Sclerotis punctatus punctatus;* and Florida long-eared sunfish, *Xenotis megalotis marginatus.*

During an investigation conducted at the Bass Biological Laboratory, Englewood, Florida, from February 1 to June 1, 1938, 1,362 fresh-water fish including forty-one species and seventeen families were examined for parasites. Of this number 1,216 or 89.3 per cent were found to be infested with at least one species of parasite. The present paper discusses the parasites found in eight species of the family Centrarchidae.

All fish were obtained by seine hauls except the majority of those from Lake Okeechobee, which were secured from commercial fishermen. Collections were made from small ponds and roadside ditches near Englewood, the Myakka River, the Peace River and its tributaries, Horse Creek and Joshua Creek, Lake Okeechobee, and those Everglades canals where the water was not too brackish for freshwater fish. In all localities the water was slow moving or still, darkcolored, and usually choked with vegetation. The bottoms of the ponds and streams were composed of soft muck. Toward the latter part of the collecting period the dry weather and lack of rainfall resulted in the complete drying up of most of the smaller areas where fish had been secured. Some of the larger stretches of water became ponded, and many fish died.

Most of the fish were examined for parasites after preservation in formalin. This preservation hampered the identification of certain of the parasites but seemed to be the most practical method when fish were obtained at some distance from the laboratory. Many of the parasites have not yet been stained, mounted, and identified to species. Consequently, for this preliminary report many of the parasitic

forms were identified to genus only. Carr's (1936) key was followed in the identification of fish. Only eight of the sixteen species of Centrarchidae reported by him were taken. The staff of the Bass Biological Laboratory assisted in collecting the fish and furnished the equipment and laboratory facilities.

Of the 516 centrarchid fish examined 99.4 per cent were parasitized. This degree of parasitization is higher than was found in the same species of fish from other localities. Of 419 centrarchid fish examined from Lake Erie in 1928 and 1929 by Dr. George W. Hunter, III, and the writer, 77.5 per cent were found to be parasitized. In 1930 at Buckeye Lake, Ohio, the writer found that 82.2 per cent of 155 centrarchids (including seven species) were parasitized. Bangham (1933) found that 63.3 per cent of thirty-three largemouth bass from Ohio streams were infested with parasites.

In spite of the high percentage of infestation, the Florida centrarchids did not contain as many different species of parasites as the Ohio specimens. The high percentage of infestation in the Florida fish was chiefly due to the presence of large numbers of larval parasites which have fish-eating birds as their adult hosts. Cestodes were encountered less frequently in Florida specimens than in the same species of fish from northern waters. The larval form of *Proteocephalus ambloplitis* (Leidy) which frequently causes great damage to bass in lakes was not taken from Florida fish. Adults of this cestode were not found in either the bass or the fresh-water dogfish, *Amia calva*. There were also fewer species of flukes in the Florida fish. Small gill flukes belonging to the family Dactylogyridae, and encysted strigeid metacercariae were present in a large number of the Florida fish. Heavy infestations of the intestinal acanthocephalan, *Neoechinorhynchus cylindratus*, were encountered in the largemouth bass. Other centrarchid fish often had numbers of encysted acanthocephalans. Gill copepods were taken somewhat more frequently than from the same species of fish from Ohio. The most striking difference between the parasitization of Ohio and Florida centrarchids was in the great abundance of larval nematodes, *Contracaecum spiculigerum* (Rud.), taken from mesentery cysts in the Florida hosts. The same form was secured from eighteen of the thirty-three additional species of fish examined from Florida. Cysts of *Neascus vancleavei* (Agersborg) were also found in great numbers about the heart, had riddled the liver, and had caused adhesions in the mesentery. Fish with heavy infestations of these larval flukes and nematodes were often thin and lacked fat about their visceral organs. The absence of fat deposits was almost the only noticeable effect of parasitism on the host.

The eight species of Centrarchidae examined for parasites were as follows: largemouth bass, *Huro salmoides;* warmouth bass, *Chaenobryttus gulosus;* bluegill, *Helioperca macrochira;* black crappie, *Pomoxis sparoides;* stump-knocker, *Eupomotis microlophus;* black-spotted sunfish, *Sclerotis punctatus punctatus;* blue-spotted sunfish,

*Enneacanthus gloriosus;* and Florida long-eared sunfish, *Xenotis megalotis marginatus.*

In the following lists of the parasites found in each species of fish, the number in parentheses indicates the number of individuals carrying the designated parasite. The asterisk preceding the name of the parasite indicates larval stages.

LARGEMOUTH BASS (EXAMINED, 86. PARASITIZED, 86.)

*Neoechinorhynchus cylindratus* (Van Cleave) (75)
*Contracaecum spiculigerum* (Rud.) (62)
**Neascus vancleavei* (Agersborg) (59)
Dactylogyridae (3 spp.) (35)
*Spinitectus carolini* Holl (16)
**Neascus amblopliti*s Hughes (14)
*Ergasilus centrarchidarum* Wright (12)
*Crepidostomum* sp. (5)
**Clinostomum marginatum* (Rud.) (6)
*Leptorhynchoides thecatus* (Linton) (4)
*Paramphostomum stunkardi* Holl (3)
*Argulus flavescens* Wilson (3)
**L. thecatus* (in cysts) (2)
**Camallanus* sp. (3)
*Bothriocephalus claviceps* (Goeze) (1)
*Proteocephalus* sp. (1)
*Piscicola punctata* (Verrill) (1)

There was a more varied infestation in the largemouth bass taken from the area near Englewood than from other regions. Gill flukes were more abundant in the bass secured from rivers. Gill copepods were not found on large numbers of bass; the heaviest infestation was encountered on fish from the Peace River tributaries. Copepods were also obtained from the gills of bass from the Myakka River and Lake Okeechobee. The bass from the Myakka River showed a slightly heavier infestation with the three most common parasites, *N. cylindratus, C. spiculigerum,* and *N. vancleavei.* The thin condition and lack of fat was very noticeable in heavily infested bass.

WARMOUTH BASS (EXAMINED, 143. PARASITIZED, 143.)

**C. spiculigerum* (116)
**N. vancleavei* (100)
Dactylogyridae (sp.) (85)
*Intestinal nematodes (50)
*P. stunkardi* (30)
*Anallocreadium* sp. (28)
*Cestode cysts (19)
Dactylogyridae (sp.) (15)
**L. thecatus* (in cysts) (9)
*P. punctata* (7)
*Crepidostomum cornutum* Osborn (5)
**C. marginatum* (4)
**Camallanus* sp. (4)
**Eustrongylides* sp. (4)
*N. cylindratus* (3)
*Achtheres micropteri* Wright (3)
*A. flavescens* (2)
**Bothriocephalus* sp. (2)
*Dichelyne* sp. (2)
*Capillaria* sp. (2)
*Proteocephalus* sp. (2)
*Alloglossidium corti* (Lamont) (1)

The two entries for Dactylogyridae represent different, unidentified species.

Although the largest number of warmouth bass was examined from the Englewood ponds and ditches and from Lake Okeechobee, they were also found at every seining location. They were second in abundance to the gars. The cysts of the nematode, *C. spiculigerum,* were found in over two-thirds of the warmouth bass; the infestation was somewhat heavier in the fish from the Peace River and the Ever-

glades canals. The heaviest infestation with *N. vancleavei* was found in the specimens secured from the Everglades canals and the Myakka River, where all of the fish examined had this larval form. One-half of the warmouth bass from other locations had cysts of *N. vancleavei*. Gill flukes were found in the largest numbers in fish from three localities—Lake Okeechobee, the Everglades canals, and the Englewood region. Very few gill flukes were encountered in specimens examined from the Myakka and Peace Rivers. Mueller (1937) in a report on a study of parasites that belonged to the Gyrodactyloidea stated that the warmouth bass appears to be immune to the form, although he had not examined a sufficient number of this species to form definite conclusions. Flukes belonging to the family Allocreadiidae were taken from about one-fourth of the warmouth bass examined. The heaviest infestation with this form was found in the Lake Okeechobee fish. *P. stunkardi,* which was evenly distributed as regards habitat of the host, occurred in about one-fourth of these fish. *A. micropteri* was found only on warmouth bass from the Peace River area.

BLUEGILL (EXAMINED, 104. PARASITIZED, 103.)

**N. vancleavei* (91)
Dactylogyridae (sp.) (30)
Gill copepods (21)
**Camallanus* sp. (19)
**L. thecatus* (in cysts) (19)
**C. spiculigerum* (12)
*Capillaria catenata* Van Cleave and Mueller (10)
*Anallocreadium* sp. (6)
*S. carolini* (6)
**N. amblopltis* (6)
*P. stunkardi* (5)
*L. thecatus* (5)
*Dichelyne cotylophora* (Ward and Magath) (4)
Dactylogyridae (sp.) (3)
*N. cylindratus* (3)
**Eustrongyloides* sp. (2)
**Proteocephalus* sp. (2)
**Bothriocephalus* sp. (1)
**C. marginatum* (1)
Leech (1)

As indicated in the above list, almost all the bluegills had cysts of the strigeid trematode, *N. vancleavei*. Often the infestation was great and centered about the ventricle and liver. Few bluegills had cysts of the larval mesentery nematode, *C. spiculigerum,* found in such large numbers in many of the other host species. Heavier infestation of gill flukes occurred in fish secured from Lake Okeechobee and the Everglades canals than in specimens from other localities. Almost all of the bluegills that had gill copepods were from Lake Okeechobee. A few copepods were taken from the fish secured in the Myakka and Peace Rivers but no individuals from other areas had copepod infestations.

BLACK CRAPPIE (EXAMINED, 18. PARASITIZED, 18.)

**C. spiculigerum* (13)
**N. amblopltis* (5)
*L. thecatus* (5)
*Intestinal nematodes (3)
**Camallanus* sp. (2)
**N. vancleavei* (2)
**Proteocephalus* sp. (2)
Allocreadiidae (2)
Dactylogyridae (1)
*N. cylindratus* (1)

Too few black crappies were studied to provide accurate knowledge

concerning the distribution of the parasites. All of the fish were secured from three localities—the Peace and Myakka rivers, and Lake Okeechobee. *N. amboplitis* was found only on the black crappies from the Peace River. All but five of the fish had *C. spiculigerum* encysted in the body cavity. The life cycle of this species which was found in seven of the centrarchid host species was discussed by Thomas (1937).

STUMP-KNOCKER OR SHELL-CRACKER (EXAMINED, 90. PARASITIZED, 88.)

Dactylogyridae (sp.) (54)
*N. vancleavei* (46)
Allocreadiidae (32)
Dactylogyridae (sp.) (24)
*L. thecatus* (in cysts) (22)
*Intestinal nematodes (20)
*C. spiculigerum* (16)
Dactylogyridae (sp.) (10)
*L. thecatus* (in intestine) (9)
*P. punctata* (8)
*A. flavescens* (5)
Gill copepods (4)
**Camallanus* sp. (4)
**N. amboplitis* (3)
*N. cylindratus* (2)
*Dichelyne* sp. (2)
*P. stunkardi* (2)
*Capillaria* sp. (2)
**C. marginatum* (1)

The greatest variety of parasite species was secured from the stump-knocker taken from the ponds and roadside ditches near Englewood. *N. vancleavei* and flukes belonging to the Allocreadiidae were most abundant in the fish from the vicinity of Englewood and from Lake Okeechobee. The gill flukes were very numerous; at least three species were found on the stump-knockers.

BLACK-SPOTTED SUNFISH (EXAMINED, 49. PARASITIZED, 49.)

**N. vancleavei* (45)
Allocreadiidae (23)
Dactylogyridae (13)
*Nematodes (in intestine) (13)
Gill copepods (12)
**L. thecatus* (in cysts) (12)
**C. spiculigerum* (11)
**Camallanus* sp. (6)
Dactylogyridae (sp.) (4)
*L. thecatus* (in intestine) (4)
**N. amboplitis* (3)
*Bothriocephalus* sp. (2)
*P. stunkardi* (1)
*Leech* (1)

Next to the bluegill the black-spotted sunfish had the heaviest infestation of *N. vancleavei.* The largest number of Allocreadiidae was secured from fish in the Englewood region and from Lake Okeechobee. These same flukes were found in greatest number in other centrarchid hosts examined from these localities. Flukes belonging to the Allocreadiidae were found in 50 per cent of the black-spotted sunfish from the Myakka River, but were not present in this species from the other two areas. About 50 per cent of the black-spotted sunfish examined from the Englewood area and the Everglades canals had gill flukes, but a much lower percentage of infestation occurred in the other areas. All black-spotted sunfish from the Everglades canals carried *C. spiculigerum*, but few from other areas had this parasite.

BLUE-SPOTTED SUNFISH (EXAMINED, 12. PARASITIZED, 12.)

**N. vancleavei* (12)
**C. spiculigerum* (8)
*Nematodes (in intestine) (1)
*L. thecatus* (1)

All of the blue-spotted sunfish were taken from one locality, a small pond west of Lake Okeechobee. Consequently, no statement can be made concerning the distribution of its parasites.

FLORIDA LONG-EARED SUNFISH (EXAMINED, 14. PARASITIZED, 14.)

| | |
|---|---|
| **Contracaecum* sp. (9) | **N. vancleavei* (3) |
| Dactylogyridae (8) | *Acanthocephala (in cyst) (1) |
| *Nematodes (in intestine) (3) | Fluke (in intestine) (1) |

Five of these fish were secured from a small stream flowing into the Peace River. All carried gill flukes. Three of the Florida long-eared sunfish harbored *N. vancleavei* and three others had larval nematodes in the intestines. The remainder of the long-eared sunfish, which were taken from a roadside ditch near Englewood, were without *N. vancleavei* and intestinal nematodes, but each host carried from forty to three hundred tiny *Contracaecum* sp. in the body cavity. One individual contained an encysted acanthocephalan and an unidentified adult fluke.

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## DISCUSSION

THE PRESIDENT: Do any of those parasites in the early stages affect the fish as a food?

DR. BANGHAM: No, I think not. There were no flesh parasites.

MR. SURBER: We have noticed in our studies of the smallmouth bass in the South Branch of the Potomac River that the livers of the fingerling smallmouth bass are severely infested with cestodes, whereas very few are found in the bass of the Shenandoah River. Can Dr. Bangham suggest any reason for this difference in the abundance of parasites in the two rivers. In the Potomac River there is a large number of snails and in the Shenandoah River there is not.

DR. BANGHAM: That explains it. The first stage of the parasite is found in snails, the adult stage in birds.

# NOTES ON THE USE OF DERRIS AS A FISH POISON

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## ABSTRACT

Fisheries workers are finding that powdered derris root is a valuable aid in the elimination of undesirable fish populations. The history of this substance is presented briefly. The early use of derris root as a fish poison and as an ingredient of arrow poisons, and its development as an insecticide are mentioned. Recent papers dealing with its physiological effect on fishes are reviewed.

In a series of laboratory experiments it was found that certain species of fresh-water fishes are killed much more readily by derris than are others. The action proved to be somewhat faster in acid than in alkaline waters. Toxicity in an experimental aquarium dropped below the lethal point for fish between twenty and forty-one hours after addition of poison. Toxicity of a stock suspension of 1:100 concentration was reduced by nearly 70 per cent after standing in a darkened closet for thirty-four days. An increase in water temperature from 60° to 74°F. reduced the time of death almost by half. A considerable deterioration was detected in the strength of commercial powdered derris that was exposed to air and subdued light over a period of six months.

A concentration of one part powdered derris root (warranted rotenone content 5 per cent) to two million parts of water was found to be sufficient to kill all species of fish tested. Furthermore, no fish was able to survive after the loss of equilibrium, even though transferred to pure, aerated water.

## INTRODUCTION

In view of the increased interest currently expressed in the use of derris as a fish poison, and because reliable information concerning the concentrations in which it becomes lethal is lacking, a series of laboratory experiments was conducted in the hope of acquiring some of the data requisite to a better understanding of its use.

Fisheries managers sometimes find it expedient to remove an entire fish population from a body of water. This procedure may be employed to eliminate stunted populations or coarse fish to make room for more desirable species; as a means for the removal of infectious disease; or to obtain data on the relation of natural fish supplies to the inherent productive capacity of a water. Complete elimination of a fish fauna by means of nets is practically impossible; dynamite is expensive and uncertain as to results; and copper sulphate usually destroys fish food organisms and plants as well as fish. Derris, on the other hand, appears to be highly efficient; its cost is reasonable; and there is every indication that plants and fish-food organisms are not harmed by concentrations adequate to kill fish.

The purpose of this report is to place on record the results of certain experiments directed toward the discovery of the minimum lethal dosage of derris for various species of fish at different sizes, at different

temperatures, and under different chemical conditions of the water.

Rotenone ($C_{23}H_{22}O_6$), the most toxic principle found in the roots of various Leguminosae, was first obtained in crystalline form by the Japanese chemist Nagai (1902). It has been derived from a number of different plants, but commercial supplies, marketed under the name of "derris," are prepared chiefly from species of the genus *Deguelia* (= *Derris*), especially the oriental *D. elliptica*. Associated with rotenone are deguelin, tephrosin, and toxicarol. None of these substances is as virulent as rotenone.

It is probable that primitive peoples have used derris as a fish poison since prehistoric times. Among the earlier accounts, in which the root is usually referred to as "tuba," or "akar-tuba," is that of Marsden (1811), who stated that natives of Sumatra employed juice from the pounded root to stun and kill marine fish left stranded by the tide in coral ledge pools. Hose and McDougall (1912) described the ceremonies attending a "tuba" fishing party conducted by Dyaks of Sarawak, and showed that they have developed a number of legends and superstitions connected with the use of the poison. Newbold (1839) and others have mentioned the use of tuba, or derris root, in combination with other vegetable alkaloids, as an ingredient of arrow poisons prepared by Malaysian tribes.

Although relatively few publications have dealt with derris in its original role of fish poison, there is a most voluminous literature bearing on other aspects. Oxley (1848) reported that derris could be employed as an insecticide. Experiments on this use continued, increasing greatly during the past fifteen years. Roark (1932) gave abstracts of 456 separate publications that appeared between 1747 and 1931, all of which concern derris. Some of these publications are taxonomic in character, but the majority report on chemical analyses and insecticidal uses. At the present time the manufacture of insecticides absorbs almost all of the commercial derris output.

Investigators are generally agreed that although large doses of rotenone may prove fatal to man (Campbell, 1916, cited a case of suicide in Singapore by eating derris root), lethal dosages are not to be acquired by eating fruit sprayed with it. Haag (1931) swallowed an amount of rotenone equal to 2.3 grains without harmful effects. Workers who handle the material in its finely pulverized commercial form often notice severe nose and throat irritations. On several occasions I have experienced a sharp headache within from ten to fifteen minutes after first feeling respiratory irritation from powder inhalation. All of these symptoms can be avoided by protecting the nose with a folded cloth. Birdsall (1933) remarked that irritation from dust during the process of grinding the root is frequent, but stated that a worker who was exposed to it over a period of two years suffered no permanent ill effects.

It is apparent that in fish the toxic effect of rotenone is exerted chiefly upon the respiratory system. Daneel (1933) tested the physio-

logical action on various fishes, especially the crucian carp, *Carassius vulgaris*. He employed pure rotenone crystals, which he dissolved in acetone before preparing his aqueous test solutions. Comparisons of the oxygen consumption of fish in a 1:100,000 rotenone solution with that of the controls revealed that within ten minutes the oxygen consumption dropped to 3 per cent of the normal as the rotenone took effect. Histological examination of the gill filaments of fish killed in this way demonstrated a withering and breaking-down of the gill epithelium, which obviously destroyed its respiratory function. Scheuring and Heuschmann (1935) tested the toxicity of various concentrations of powdered derris root on trout, minnows, and perch, as well as on a variety of aquatic insects, snails, and crustaceans. Their results confirm the findings of Daneel as regards the corrosive and histolytic action of rotenone on gill epithelium. They found little ground for considering it very toxic to fish as a stomach poison. The utility of their numerous and well-conducted experiments is limited by the fact that the rotenone content of their powdered derris root was not certainly known. Roark (1931) has noted that the rotenone content of derris root may vary from 0 to 5.5 per cent, and that the total ether extract of the root, including such toxic substances as deguelin, tephrosin, and toxicarol, may vary from 5 to 23 per cent. Consequently, it is difficult to apply Scheuring and Heuschmann's dosages to the commercial powdered derris root of the United States, whose rotenone content is standardized at 5 per cent.

Gersdorff (1930a, 1930b, 1931 and 1937) has published a series of reports on the toxicity of rotenone and its associated toxic compounds and chemical derivatives, using the goldfish (*Carassius auratus*) as the test animal.

## Experimental Methods

The following species of fish were used in the experiments reported here: bluegill (*Lepomis macrochira*), common sunfish (*Lepomis gibbosus*), common sucker (*Catostomus c. commersonnii*), golden shiner (*Notemigonus c. crysoleucas*), common shiner (*Notropis cornutus frontalis*), brook stickleback (*Eucalia inconstans*), mud minnow (*Umbra limi*), and goldfish (*Carassius auratus*). Invertebrate food organisms tested included damselfly nymphs (*Argia* sp.), stonefly nymphs (*Acroneuria* sp.), adult aquatic Hemiptera (corixids, and water bugs, *Belostoma* sp.), caddisfly larvae (Limnephilidae), cranefly larvae (*Tipula* sp.), crayfish (*Cambarus propinquus*), scuds (*Hyalella knickerbockerii*), and snails (*Physa* sp.).

Experiments were conducted in waters of known chemical content derived from three sources—a spring supplying the Drayton Plains State Fish Hatchery, tap water from the Ann Arbor (Michigan) water supply, and acid water from Spruce Lake, a small bog lake near Ann Arbor, Michigan. Aquarium facilities were made available through the courtesy of Prof. F. M. Gaige, Director of the Museum of Zoology, and

Dr. Carl L. Hubbs, Curator of Fishes, University of Michigan. Fenton Carbine and John Greenbank, of the Institute staff, assisted in the collection of specimens and the water analyses.

A majority of the experiments was carried on in glass aquaria of 12-liter capacity. Ten liters of water were added to these aquaria, which were then immersed almost to the upper rim in water circulating through large tanks. By adjusting the rate of flow it was possible to maintain a temperature of 60° ±1°F. A few experiments were carried out in a heated aquarium room at a water temperature of 74°F.

Stock poison suspensions were made by mixing 10 grams of powdered derris root with 1,000 cubic centimeters of water. Varying amounts of this stock were used in the different experiments. The derris was warranted by the manufacturer to possess a rotenone content of 5 per cent.

The derris concentrations given in this report are based on the proportion of powdered derris root to water by weight, *not* the proportion of rotenone to water.

Controls were maintained on all experiments. The effect of rotenone on various invertebrates was tested by placing them in small screen-wire cages immersed in the test suspension.

## Experiments on the Toxicity of Derris to Fish

With the exception of goldfish and mud minnows, all of the fish tested displayed a rather uniform type of behavior. The first discernible indication that the poison is felt is a wild, erratic, and apparently uncontrolled dashing and plunging. The fish moves at top speed, throws itself blindly against the aquarium walls, and swims on its side or back almost as frequently as in the normal position. This flurry, which may last from five to thirty seconds, usually takes the fish to the surface, where it breaks water repeatedly. The seizure terminates in a convulsive stiffening of the body, accompanied by uncoordinated twitching of the fins and tail. In this condition the fish drifts slowly to the bottom of the tank, where it comes to rest on its side. Here it may lie, for from two to ten seconds, with no movement other than a spasmodic fluttering of the operculum. At the end of this short period the fish usually rights itself and swims calmly about in the usual manner, although it may rise to the surface and gulp air repeatedly. Death may not ensue for many hours, during which time the above procedure is

**TABLE 1. EFFECT OF THE LENGTH OF TIME A DERRIS SUSPENSION STANDS ON ITS TOXICITY TO COMMON SUNFISH IN AERATED SPRING WATER AT 60° F. ORIGINAL CONCENTRATION, 1.00 p.p.m.**

| Number of fish | Average standard length in inches | Time between addition of derris and start of experiment | Average time of loss of equilibrium in minutes | Average time of death in minutes |
|---|---|---|---|---|
| 3 | 3.5 | 30 minutes | 108 | 220 |
| 2 | 3.5 | 20 hours | 38 | 65 |
| 2 | 3.5 | 40 hours | [1]---- | [1]---- |

[1]No loss of equilibrium occurred; the fish were alive after seventy-two hours.

likely to be repeated several times. On each succeeding occasion the flurry of activity is shorter, and the quiescent period longer in duration. In time a condition verging on paralysis appears. The fish is capable of convulsive movement when strongly stimulated, as by pinching with forceps, but disregards frightening motions made by the observer, and lies still on the bottom or drifts aimlessly with water currents, with no sign of life other than an occasional weak movement of the operculum. The actual moment of death is not easily determined. After all detectable response to mechanical stimuli has passed, life may persist. The method of Gersdorff (1937), who confirmed death by dipping the fish into a 1:3 concentration of hydrochloric acid, was adopted in these experiments.

The first three experiments (Table 1) were directed at the discovery of the speed with which toxicity of rotenone is dissipated in standing water. The derris suspension was added to an aquarium containing five fish. These died as noted in the table. Twenty hours later two more sunfish were added and killed. Forty-one hours after addition of the poison, two more sunfish were placed in the tank, where they remained for seventy-two hours without displaying any signs of distress. This fact led to the obvious conclusion that the toxic effect dropped below the lethal point for sunfish of this size between twenty and forty-one hours after the addition of the poison. The average time of death of the first lot is based upon three specimens only. One individual was removed to pure, aerated water when almost incapable of movement. A second was treated similarly immediately after it first showed signs of distress and temporary loss of equilibrium. The first of these two died 310 minutes after addition of the derris; the second succumbed after thirty-seven hours, without regaining normal responses or behavior.

**TABLE 2. EFFECT OF DIFFERENT CONCENTRATIONS OF DERRIS ON COMMON SUNFISH, COMMON SUCKER, COMMON SHINER, GOLDEN SHINER AND MUD MINNOW IN AERATED SPRING WATER AT 60° F.**

| Species | Number of fish | Average standard length in inches | Concentration in parts per million | Average time of loss of equilibrium in minutes | Average time of death in minutes |
|---|---|---|---|---|---|
| Common sunfish | 2 | 3.5 | 1.00 | 64 | 77 |
| Common sunfish | 2 | 3.5 | 0.50 | 63 | 102 |
| Common sunfish | 2 | 3.5 | 0.25 | [1]--- | [1]--- |
| Common shiner | 2 | 2.5 | 0.50 | 35 | 75 |
| Common sucker | 2 | 3.0 | 0.50 | 67 | 102 |
| Golden shiner | 2 | 2.0 | 0.50 | 67 | 108 |
| Mud minnow | 1 | 3.5 | 0.50 | 528 | 628 |

[1]No loss of equilibrium occurred; the fish were alive after ninety-six hours.

In Table 2 are shown the results of decreasing derris concentrations on common sunfish. It will be noted at once that there is no very great difference between the velocity of the toxic action of concentrations of 1.00 and 0.50 p.p.m. The concentration of 0.25 p.p.m. proved to be

wholly without effect; no sign of distress was detected throughout the 96-hour period of the experiment. This result is in sharp contrast to the findings of Scheuring and Heuschmann (1935), who found that a concentration of 0.20 p. p. m. killed a trout and two perch in an hour and thirty-five minutes, and a rudd in five hours and twenty minutes. In a concentration of 0.10 p. p. m. they killed two trout in three hours and twenty minutes. It seems obvious that their derris root was of considerably higher toxicity than the domestic commercial supply assayed to possess a rotenone content of 5 per cent.

From Table 2 it will also be seen that the common shiner is much more sensitive to derris than is the common sucker. A comparison with Table 3 shows the sensitivity of the common sucker to be about the same as that of the sunfish and bluegills tested.

The high resistance of the mud minnow is also shown in Table 2. It was difficult to determine the point at which this species was first affected. At no time did the individual enter into the violent seizure of plunging that was common to most of the specimens of the other species tested, but simply grew gradually and almost imperceptibly more lethargical in its movements. Time of loss of equilibrium was also difficult to determine accurately, for the fish spent most of its time resting on the bottom of the aquarium, braced by its fins.

TABLE 3. EFFECTS OF DIFFERENT CONCENTRATIONS OF DERRIS ON BLUEGILLS, COMMON SUCKER, GOLDEN SHINER AND GOLDFISH IN AERATED SPRING WATER AT 60° F.

| Species | Number of fish | Average standard length in inches | Concentration in parts per million | Age of stock suspension | Average time of loss of equilibrium in minutes | Average time of death in minutes |
|---|---|---|---|---|---|---|
| Bluegill | 6 | 1.8 | 1.00 | 29 hours | 35 | 85 |
| Bluegill | 3 | 1.8 | 0.50 | 4 days | 57 | 102 |
| Bluegill | 6 | 1.6 | 0.50 | 10 days | 80 | 114 |
| Bluegill | 5 | 1.4 | 0.25 | 10 days | 109 | [1]180 |
| Golden shiner | 5 | 2.5 | 0.50 | 34 days | 83 | 440 |
| Common sucker | 2 | 2.7 | 0.50 | 34 days | 85 | [2]440 |
| Goldfish | 5 | 1.6 | 0.50 | 34 days | 114 | 2,617 |

[1]One individual only. Remaining four alive after ninety-six hours.
[2]One sucker succumbed after twenty-five hours and forty minutes.

Table 3 summarizes two groups of experiments conducted to verify the data not only on the effect of different concentrations, but also on the loss of toxicity by the stock derris suspension (10 grams powdered derris root to 1,000 cubic centimeters water). This suspension had been tightly sealed, and stored in darkness. It will be seen that in ten days' time a very slight decrease in toxicity had occurred.

One lot of poison used in these experiments had been mixed, in the usual proportions, thirty-four days earlier. Although the bottle had been kept tightly stoppered and in a dark closet, a thin layer of black, evil-smelling mold had formed on the surface. The times of death

indicate that during this period the toxicity of the stock suspension had decreased by between 60 and 70 per cent.

Three aquaria were employed in the experiments recorded in Table 4. Twenty goldfish were placed in 20 liters of water in a large tank, and ten goldfish were placed in 10 liters of water in a smaller tank. The water temperature in both of these was held at 60°F. Fifteen goldfish were placed in another small tank in 10 liters of water at a temperature of 74°F. It will be seen that the 14-degree elevation of temperature cut the points of equilibrium loss and death to almost one-half the time required at 60°F.

**TABLE 4. EFFECT OF TEMPERATURE ON THE TOXICITY OF DERRIS TO GOLDFISH IN AERATED TAP WATER. SEE TEXT FOR DETAILS OF EXPERIMENT**

| Number of fish | Average standard length in inches | Concentration in parts per million | Water temperature | Average time of loss of equilibrium in minutes | Average time of death in minutes |
|---|---|---|---|---|---|
| 30 | 1.7 | 0.50 | 60°F. | 455 | 1,042 |
| 15 | 1.6 | 0.50 | 74°F. | 261 | 565 |

An attempt was made to observe the effect of derris in naturally acid water. For this purpose a supply of water was obtained from Spruce Lake as noted above. After five goldfish had been left in this water for a 24-hour acclimatization period, a reading of pH 6.5 was obtained with a Hellige pH outfit. A second determination after all the fish had died showed that no change in acidity had taken place. As a control, five goldfish were placed in tap water with a pH of 8.2, and with the same concentration of derris. The results, recorded in Table 5, show a surprising acceleration in velocity of toxic action for individuals in the acid water. Unfortunately, this experiment was interrupted at the end of a little more than sixteen hours. At this time none of the fish in the alkaline tank had died, but all had lost their equilibrium and doubtless would have succumbed soon.

**TABLE 5. EFFECTS OF IDENTICAL CONCENTRATIONS OF DERRIS ON GOLDFISH IN NON-AERATED TAP WATER AND BOG LAKE WATER AT 60° F.**

| Number of fish | Average standard length in inches | Concentration in parts per million | pH of water | Average time of loss of equilibrium in minutes | Average time of death in minutes |
|---|---|---|---|---|---|
| 5 | 1.6 | 0.50 | 6.5 | 184 | 269 |
| 5 | 1.6 | 0.50 | 8.2 | [1]—— | [1]—— |

[1]All alive, but equilibrium lost, after 985 minutes.

In order to obtain additional information on the effect of derris on fish in acid water, a special experiment with golden shiners (which were already known to be very sensitive to derris) and brook stickle-

backs was set up. The results, shown in Table 6, indicate that the increase in velocity of toxic action in acid water is much more marked in resistant species, such as goldfish (Table 5), than in sensitive fish.

TABLE 6. EFFECT OF IDENTICAL CONCENTRATIONS OF DERRIS ON GOLDEN SHINERS AND BROOK STICKLEBACKS IN AERATED AND UNAERATED TAP WATER AND UNAERATED BOG LAKE WATER AT 60° F. AND WITH A DERRIS ROOT CONCENTRATION OF 0.50 p.p.m.

| Species | Number of fish | Average standard length in inches | Source of water | Average time of loss of equilibrium in minutes | Average time of death in minutes |
|---|---|---|---|---|---|
| Stickleback | 5 | 1.7 | Bog | 22 | 236 |
| Shiner | 7 | 1.6 | Bog | 20 | 194 |
| Stickleback | 5 | 1.7 | Unaerated tap | 35 | 242 |
| Shiner | 4 | 1.6 | Unaerated tap | 30 | 257 |
| Stickleback | 6 | 1.6 | Aerated tap | 56 | 267 |
| Shiner | 6 | 1.8 | Aerated tap | 48 | 208 |

Table 7 shows results of an experiment devised to test loss of toxicity by commercial powdered derris root. Two stock suspensions were made up in the usual proportions. One was prepared with derris received from the manufacturer and unpacked only a few hours before mixing. The other was prepared with a lot which had been exposed to air and subdued light over a period of six months. Both lots were obtained from the same manufacturer, and were warranted to possess a rotenone content of 5 per cent. On the basis of figures obtained in this test, it was concluded that the 6-month-old lot had sustained a loss in toxicity of approximately 43 per cent.

TABLE 7. EFFECT OF THE AGE OF COMMERCIAL STOCKS OF DERRIS ON THEIR TOXICITY TO GOLDFISH IN UNAERATED TAP WATER AT 60° F.

| Number of fish | Average standard length in inches | Derris supply | Concentration in parts per million | Average time of loss of equilibrium in minutes | Average time of death in minutes |
|---|---|---|---|---|---|
| 5 | 1.7 | New | 0.50 | 366 | 709 |
| 5 | 1.8 | Old | 0.50 | 528 | [1]1,245 |

[1]One still alive after 4,978 minutes.

## Toxicity of Derris to Invertebrates, Fish Eggs and Fry

A variety of insects, crustaceans, and snails was imprisoned in screen-wire cages and immersed in a derris concentration of 1.00 p.p.m. where they were held for ninety-six hours. At the end of this time, none, not even the stonefly nymphs, showed the slightest sign of distress. Scheuring and Heuschmann (1935) found that most aquatic invertebrates were killed only by very strong concentrations. For example, they found that *Chironomus* and *Gammarus* were killed in one or more hours by a concentration of 20 p.p.m. *Daphnia* succumbed in

from 1.5 to 4 hours in a concentration of 5 p.p.m. It would therefore appear improbable that a dosage intended to eradicate a fish population would affect the food supply.

An attempt was made to observe the effect of derris on fish eggs. A small number of eyed brown trout eggs was supplied by the Paris State Fish Hatchery. These eggs were divided into two equal lots, one of which was placed in a tank of pure, aerated water, the other in a tank of aerated water containing derris in a concentration of 0.50 p.p.m. Seventy-two hours later, the eggs in both tanks began to hatch. The fry in pure water emerged successfully, and swam about. Although approximately an equal number hatched in the poison tank, not one was able to free itself completely from the egg. A pair of 1.5-inch bluegills placed in the poison tank when hatching commenced were unaffected, but the suspension appeared to be sufficiently toxic to kill the emerging fry. It was obvious that the eggs themselves were not killed by the poison.

## Summary

1. In the laboratory the toxicity of a concentration of 1.00 p.p.m. commercial powdered derris root, possessing a warranted rotenone content of 5 per cent, dropped below the lethal point for common sunfish and bluegills between twenty and forty-one hours after preparation.
2. A derris concentration of 0.50 p.p.m. was only slightly less toxic than one of 1.00 p.p.m., as tested on common sunfish and bluegills. A concentration of 0.25 was not lethal to these species.
3. Of the species tested the least resistant to the action of derris were: common shiner, golden shiner, bluegill, common sunfish, and brook stickleback. The mud minnow and the goldfish were the most strongly resistant.
4. Goldfish succumbed to the action of derris much more rapidly in acid than in alkaline water. In the less resistant species acidity of the suspensions had less effect on the toxicity.
5. Once a fish lost its equilibrium it was doomed, even though transferred to pure water.
6. Powdered derris root loses toxicity rather rapidly after it is mixed with water. Even though protected from light and air, a 1 per cent stock suspension lost between 60 and 75 per cent of its toxicity in thirty-four days.
7. Powdered derris root loses toxicity upon exposure to air. One lot lost approximately 43 per cent of its toxicity over a period of six months during which time it was exposed to air and subdued light.
8. All of the aquatic invertebrates tested were unaffected by exposure to a derris concentration of 1.00 p.p.m. over a period of ninety-six hours. This observation indicates that fish may be killed by derris without affecting fish-food organisms.
9. Eyed brown trout eggs were not killed in a derris concentration of 0.50 p.p.m., but the fry perished as soon as they broke the shell,

even though the toxicity had by that time dropped below the point lethal to small bluegills.

10. A derris concentration of 0.50 p.p.m. was found to be the lowest that is certain to kill fish of all species.

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## Discussion

Dr. Gustave Prevost: Which way do you introduce the derris in the lake?

Dr. Leonard: The best method is to put the powdered derris root into suspension in water, making up a sort of batter. We have found it quite convenient to apply it by pouring the suspension into one of the portable tanks used by forest-fire fighters. These tanks may be placed in a boat or carried on the back around the shore of the lake. One may simply pump the suspension into the lake and get very good distribution. Afterward, if it is thought desirable and the equipment is available, we drive a motorboat over the lake at high speed to assist in mixing. Rotenone is not soluble in water; it is soluble in acetone or benzine. However, this suspension seems to be quite as lethal to fish as when the drug is first dissolved in acetone and then dissolved in water.

Dr. Prevost: Has it been tried in any lakes?

Dr. Leonard: It has been tried several times by our staff, and by other workers, too. At first the method was to apply the derris until some fish showed signs of distress. The reason these experiments were attempted was that we thought we were probably wasting derris by using more than was required.

A concentration of one part in two million is apparently amply strong. Trout and other susceptible species could probably be killed by a concentration of one part in three or four million, but if you have such species as bullheads or carp we feel that a one-half p. p. m. concentration is advisable. It was very obvious that even a 1 p. p. m. concentration was not harmful to the food organisms tested.

Dr. Prevost: What was the depth of the lake you treated?

Dr. Leonard: I think the deepest lake we have tried it on is about 70 feet deep. In that lake we were quite sure that all the fish were killed. The lake has a surface area of about 10 acres.

Mr. William Adams: Could you treat a lake a mile and a half long, a mile wide and 60 feet deep?

Dr. Leonard: If you really desire to get all the fish out, while it is expensive, it can be done.

Mr. Adams: I think all through the northern part of the northeast section of the United States we have under-developed yellow perch that have largely pre-empted some of our lakes that at one time were "squaretail" lakes. We can accelerate a change of balance by trapping out large quantities of those yellow perch and putting in good-sized fish of the type of lake trout or squaretails that will feed upon the smaller perch. Can derris be applied locally? Suppose you had a long, deep cove, a well-known spawning area for yellow perch. Could you treat that one long deep cove and not the lake as a whole?

Dr. Leonard: I am quite sure that this could be done. I think you should try to pick a day when there is very little wind, and when the wave action is as slight as possible. Although you would have to expect the effect of the poison to spread out a little into the deeper water, I feel you could reduce the population very greatly in that cove.

MR. W. H. CHUTE: You say that one part in two million is the proper application for a small pond? How soon would it be safe to put fish in again?

DR. LEONARD: There is a situation where I don't think it would be perfectly safe to apply the laboratory results. The toxicity disappears sometime between twenty and forty hours after the first addition of poison to the tanks. I don't think it would be safe to say that under natural conditions that time would be sufficient. However, I think a week or ten days would surely be adequate for the disappearance of the poison. If your pool has an outlet the toxicity loss would be accelerated.

MR. CHUTE: The pool I have in mind has no outlet.

DR. LEONARD: Persistence of toxicity could be tested simply by throwing in a few minnows or any small fish that you might have available, to see if they were affected. The symptoms are very marked. If the poison is still present they will soon come to the surface, start gulping air, and commence an erratic plunging about.

We are not certain as to the effect of derris on livestock. Experiments show that the toxicity of derris and rotenone is much greater to cold-blooded vertebrates than to warm-blooded vertebrates, but I do feel that considerable caution should be used in poisoning a water that is frequented by cattle for the purpose of drinking.

MR. ADAMS: Could fish so killed be ground up and used in the hatchery to feed other fish?

DR. LEONARD: I am not certain that they could. I might say that there is a chemical test which detects the presence of very small quantities of rotenone in water. I am not a chemist and I don't remember its details, but it is a rather simple test, and information on it can be found in the publications of Dr. Gersdoff. It is a color test.

MR. ADAMS: To what extent is derris used in mosquito control?

MR. H. S. SWINGLE: Not at all.

DR. LEONARD: It is true that derris has been used as a mosquito killer. There has been some such work done in Canada.

MR. ADAMS: Mr. Chairman, I regard this as an extremely important paper and an extremely valuable discussion for the reason that it fits in with our conception of fish management of wild stocks of fish as distinguished from supplementing that supply by artificial propagation and planting. If research in this particular field should some day give us formulas and methods, that will be as important to us as the researches we are carrying on now in the poisoning of trees and the use of fire in the control of vegetation in game management.

We know now that in game management in the future, poison and fire are going to be two of our most important means of controlling the cover. Our research, of course, has only begun in those two fields, but in our own work we have progressed to the point in the poisoning of trees where we believe we are passing beyond the experimental stage. If we can kill trees, for example, and do not have to cut them down, so as to get the sunlight in on the flora, we will have accomplished about all we want to try to accomplish in that particular direction.

Now, if we can work out partial control of certain species of fish in a body of water by poisoning them in the spawning area, where they are localized temporarily, we will have opened up a wonderful field of possibilities for us.

# SPECIES COMPOSITION BY AGE GROUPS AND STABILITY OF FISH POPULATIONS IN SECTIONS OF THREE MICHIGAN TROUT STREAMS DURING THE SUMMER OF 1937

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## ABSTRACT

Intensive studies of the fish populations in three sections of the South Branch of the Pine River, two sections of the Little Manistee River, and three sections of the North Branch of the Boardman River were carried out monthly from June to September, 1937. The same sections were blocked and seined each month and the fish found there were enumerated by species, weighed, and measured. Scale samples were collected from all trout above age-group O.

The efficiency of the block-and-seining method of stream census was tested in the most difficult section to seine (lower census section on the South Branch of the Pine River). It was found to be 89.1 per cent effective, comparing favorably with results of similar tests conducted in New Hampshire trout streams. As far as could be determined, the method was 100 per cent efficient for the enumeration of the trout population. Only the very small minnows, muddlers, and suckers escaped the first seining.

From the results of the seinings and from plane-table maps of the census sections, monthly estimates were made of the populations per acre and per mile in the censused portions of each stream. No computations for entire streams have been made because the proportion of the habitats censused is not known for any of the streams in question. The estimates for various habitats must be considered as tentative in the light of the extreme variation found in the same section in different months.

Recaptures of marked fish in subsequent months indicate that neither the trout nor the "coarse fish" tend to remain in the census areas. Calculations of stream populations on the basis of one or two counts in limited sections at any one time are therefore inaccurate.

A study of the age of the trout collected in the census sections of the North Branch of the Boardman indicated an abnormal number of trout of age-group O. In the South Branch of the Pine and in the Little Manistee the older age groups were present. The oldest trout represented by a few individuals were members of age-group III, or in the fourth year of life.

## INTRODUCTION

The management of trout waters in order to maintain dependably good angling is being discussed by fisheries biologists and fisheries administrators, but at present intelligent management would be difficult because of the lack of basic data. For example, almost no information is available concerning the composition of typical trout-stream populations, the variation in populations in different habitats, the seasonal changes to which they are subject, or the effects of angling and artificial plantings of hatchery-reared trout upon the populations. Although a number of studies have been made of the fish-food supply and of the feeding habits of trout, no one has satisfactor-

ily correlated these investigations so as to demonstrate selectivity or non-selectivity in feeding or the effect of a given number of fish upon the abundance of bottom food organisms.

Embody (1929) determined the number, species, and size of fish in a New York trout stream by temporarily diverting the flow of a short section into an old channel. Greeley developed the procedure of blocking sections of a stream for seining and Greeley and Bishop (1933) sampled a number of New York streams by that method Further results of the blocking method have been reported by Moore *et al.* (1934) in New York, and by Trippensee (1937) in New Hampshire who critically evaluated the method for different bottom types.

## Purposes and Methods

This investigation of sample sections of Michigan trout streams was made in order to:

1. Determine the number of trout present.
2. Learn the proportion of other fishes found in association with trout.
3. Discover the changes in numbers and species occurring during the summer.
4. Determine age and coefficient of condition of the trout from scale samples, weights, and measurements of the fish taken.
5. Learn the degree of stability of the various species by marking captured fish and by removing the entire population in one section each month.

The three streams investigated were the South Branch of the Pine River (Alcona County), the Little Manistee River (Lake County), and the North Branch of the Boardman River (Grand Traverse County), all Michigan streams open to public fishing. Three portions of the South Branch of the Pine and two of the Little Manistee were studied in June, July, August, and September, 1937. On the North Branch of the Boardman two sections were sampled on July 1 and 2, and three were studied during late July and mid-August. Each section was worked one day in each month. The sections were chosen at random, but the investigators who located them were instructed to select a variety of seinable habitats on each stream. The physical data and habitat characteristics of the several stream portions under consideration are presented in Table 1.

The field methods used in the census work were described by Greeley and Bishop (1933). The same methods were followed except for certain additions and refinements. Chicken wire was found to be the most suitable material for supporting the blocking seines, as shown in Figure 1. Specially constructed J-shaped iron stakes approximately 2 feet long were used to hold the lead lines of the blocking seines on the stream bottom. Plane-table maps were prepared for each census area (scale 1 inch = 10 feet) and on these depths and types of bottom were plotted. Areas were determined by use of a planimeter,

**TABLE 1. CHARACTERISTICS OF STREAM SECTIONS EXAMINED FOR POPULATIONS DENSITIES, SUMMER, 1937**

| Stream | Section | Length (feet) | Average width (feet) | Average depth (inches) | Area (square feet) | Calculated volume (cubic feet) | Calculated velocity (feet per second) | Calculated flow (cubic feet per second) | Shade[2] | Submerged cover[2] | Number of improvement devices | Bottom soils (in per cent)[3] | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | Peat | Clay | Organic muck | Gravel | Sand |
| South | Upper | 96.9 | 24.9 | 9.8 | 2,429 | 1,984 | 0.75 | 15.3 | Partly | Excellent | ---- | ---- | ---- | 17 | 81 | 2 |
| Branch of | Middle | 95.0 | 17.7 | 10.9 | 1,674 | 1,521 | 0.86 | 13.8 | Densely | Excellent | 3 | ---- | 74 | 1 | 25 | -- |
| Pine | Lower | 103.3 | 21.9 | 13.7 | 2,211 | 2,524 | 0.68 | 16.6 | Partly | Excellent | ---- | 2 | ---- | 90 | 3 | 5 |
| Little | Upper | 106.6 | 27.9 | 17.2 | 2,845 | 4,078 | 1.37 | 52.4 | Partly | Average | 2 | ---- | ---- | 2 | 33 | 65 |
| Manistee | Middle | 153.7 | 36.7 | 17.4 | 5,291 | 7,672 | ------ | [1]68.4 | Exposed | Poor | -- | ---- | ---- | 9 | 37 | 54 |
| North | Upper | 139.9 | 24.5 | 10.1 | 2,966 | 2,479 | 3.10 | 55.3 | Partly | Excellent | 1 | ---- | ---- | 5 | 65 | 20 |
| Branch of | Middle | 95.0 | 27.8 | 11.4 | 2,722 | 2,586 | 1.52 | 41.4 | Exposed | Poor | 4 | ---- | ---- | 2 | 8 | 90 |
| Boardman | Lower | 121.3 | 29.7 | 9.1 | 3,612 | 2,740 | 1.69 | 38.2 | Partly | Poor | 4 | ---- | ---- | 1 | 4 | 95 |

[1]Calculated by using velocity found in upper section.

[2]These categories based on observation and fishing experience.

[3]Percentages of different types of bottom soils were estimated for the North Branch of the Boardman. For all others, determinations were made from maps of the sections by means of a planimeter.

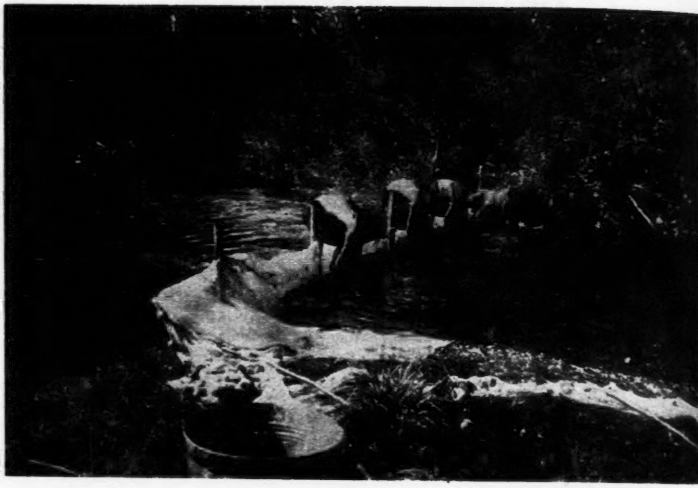

**FIG. 1.—CCC crew cleaning lower blocking seine during removal of fish from section of North Branch of Boardman River.**

**FIG. 2.—Seining the lower section of the South Branch of the Pine River. The upper blocking seine is upstream, just around the bend. Note the amount of shade and depth of water in this especially productive section.**

and linear distances with a map measurer. Stream velocities were obtained by determining the time required for a match to move 30 feet (measured distance).

Before any section was seined, a bottom-food sample was collected with a square-foot sampling net from the dominant type of bottom of that particular section so that some measure of the availability of food might be obtained for comparison later with the food found in the stomachs of fish taken from that particular section. The analyses of bottom samples and stomach contents are not discussed in this paper.

The fishes encountered during the investigation were as follows: brook trout, *Salvelinus fontinalis;* brown trout, *Salmo trutta;* rainbow trout, *Salmo gairdnerii irideus;* common sucker, *Catostomus c. commersonnii;* muddler, *Cottus cognatus* and *C. bairdii;* blacknosed dace, *Rhinichthys atratulus;* creek chub, *Semotilus a. atromaculatus;* mud minnow, *Umbra limi;* stickleback, *Eucalia inconstans;* Johnny darter, *Boleosoma n. nigrum;* golden shiner, *Notemigonus crysoleucas auratus;* yellow perch, *Perca flavescens;* bluegill, *Lepomis macrochirus;* bullhead, *Ameiurus, sp.;* lamprey, *Entosphenus lamottenii;* and crayfish, *Cambarus virilis* and *C. propinquus.*

The fish of each species were counted, weighed, and measured alive in the field. Scale samples were taken from all trout except those that were obviously young of the year. Weights were recorded in grams; standard and total lengths in millimeters. Live weights of the fish were obtained with a Chatillon spring balance (500 gram capacity) equipped with an adjustable dial. A small pan of fresh water was placed on the balance to keep the fish alive, the additional weight entailed was compensated by moving the dial to zero and the weights of the fish were read directly without the necessity for any correction.

In all but one census section of each stream the fish were released alive after the pertinent data had been recorded. Before release each fish was marked by fin-clipping; a different fin was removed each month so that when the fish were recaptured it was possible to tell when they had first been captured. The total population from one section of each stream was preserved each month for a detailed analysis of stomach contents. These fish were counted, weighed, and measured before initial preservation in 10 per cent formalin.

The efficiency of the general method of stream census was not tested as extensively as might be desired, but results from one test on the lower census area of the South Branch of the Pine River, considered the most difficult to seine, indicated that a very small percentage of fish (all species of minor importance) escaped the original count with the probable exception of the muddlers. On August 13, 1937, the lower census section was blocked and was seined in the usual manner (Figure 2) until no fish, or only an occasional muddler, was taken. At this time seining normally would have been dis-

continued. After a period of four hours, during which the section was left undisturbed with blocking nets in place, seining was resumed. The fish captured in the check seining consisted of six black-nosed dace, six common suckers, and four muddlers. These fish had a total weight of 9 grams.

After the additional seining, the entire crew of seven men lined up at the bottom blocking seine and walked slowly upstream, probing all places where fish might be concealed. Only one fish was observed, a black-nosed dace so small that it could escape through the meshes of a fine-meshed minnow seine.

During the course of the regular seining, 131 fish (Table 2) were captured, representing 89.1 per cent of the total number of fish taken in both regular and check seinings. It should be noted that no trout were caught in the second seining, and as none was observed by the careful scrutiny of the crew at the conclusion of the efficiency test, it was assumed that the entire trout population of this particular section had been captured by the regular procedure. If 89.1 per cent efficiency could be obtained in the section where seining was most difficult, probably the figures given for other sections closely approach 100 per cent.

Other tests of the efficiency of this particular method of stream census were conducted during the past summer by Trippensee (1937) in New Hampshire trout streams. All of the sections studied by us were similar to those classed by him as "relatively easy to seine." He estimated that the method was between 90 and 100 per cent efficient for that type of stream.

No corrections have been made in the calculated population per acre and per mile as given in this discussion, inasmuch as the test on the South Branch of the Pine suggests that for trout the error in method is negligible.

## Density of Fish Populations[1]

Brook, brown, and rainbow trout were present in both the South Branch of the Pine River and in the Little Manistee River, but only brook and brown trout were taken in the North Branch of the Boardman River. Common suckers, muddlers, black-nosed dace, and crayfish occurred consistently in all three streams. Creek chubs, sticklebacks, and lampreys were caught in two of the three streams. Johnny darters were taken consistently only in the Little Manistee River. The remaining species (golden shiners, mud minnows, yellow perch, bullheads, and bluegills) were seined in sections of only one stream.

Numerical results of the population studies on the various stream sections will be found in Tables 2 to 9, and consist of the monthly totals of the several species of fish found in each section, the calculated number and weight of fish per mile and per acre of stream, based on the actual number and weight of fish determined for each

[1]No artificial plantings of fish were made during the period of census.

**TABLE 2. FISH POPULATION IN SOUTH BRANCH OF THE PINE RIVER, LOWER CENSUS SECTION**
(Actual weights in grams, calculated weights in pounds. Legal trout are 7 inches, total length, and over.)

| Species | | Actual number and weight of fish in section | | | | | Calculated number and weight of fish per mile of stream | | | | | Calculated number and weight of fish per acre of stream | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | June | July | Aug. | Sept. | Mean | June | July | Aug. | Sept. | Mean | June | July | Aug. | Sept. | Mean |
| Brook trout | Legal | 2 | 5 | 2 | 2 | 2.75 | 100.0 | 250.0 | 100.0 | 100.0 | 137.5 | 39.0 | 99.0 | 39.0 | 39.0 | 54.00 |
| | Sub-legal | 9 | 8 | 3 | 4 | 6.00 | 450.0 | 400.0 | 150.0 | 200.0 | 300.0 | 177.0 | 158.0 | 59.0 | 79.0 | 118.25 |
| | Total weight | 500 | 623 | 428 | 441 | 498.00 | 55.0 | 68.5 | 47.1 | 48.5 | 54.8 | 21.5 | 26.8 | 18.4 | 19.0 | 21.43 |
| Brown trout | Legal | .... | .... | 1 | .... | 0.25 | .... | .... | 50.0 | .... | 12.5 | .... | .... | 20.0 | .... | 5.00 |
| | Sub-legal | 1 | .... | .... | .... | 0.25 | 50.0 | .... | .... | .... | 12.5 | 20.0 | .... | .... | .... | 5.00 |
| | Total weight | 25 | .... | 195 | .... | 55.00 | 2.7 | .... | 21.5 | .... | 6.1 | 1.1 | .... | 8.4 | .... | 2.38 |
| Rainbow trout | Legal | .... | 1 | 2 | 3 | 1.50 | .... | 50.0 | 100.0 | 150.0 | 75.0 | .... | 20.0 | 39.0 | 59.0 | 29.50 |
| | Sub-legal | 10 | 10 | 10 | 24 | 13.50 | 500.0 | 500.0 | 500.0 | 1,200.0 | 675.0 | 197.0 | 197.0 | 79.0 | 473.0 | 236.50 |
| | Total weight | 376 | 385 | 244 | 504 | 377.25 | 41.4 | 42.3 | 26.8 | 55.4 | 41.5 | 16.2 | 16.6 | 10.5 | 21.7 | 16.25 |
| Common sucker | | 51 | 44 | 56 | 86 | 59.25 | 2,550.0 | 2,200.0 | 2,800.0 | 4,300.0 | 2,962.5 | 1,005.0 | 867.0 | 1,103.0 | 1,694.0 | 1,167.25 |
| | Total weight | 3,607 | 3,150 | 3,640 | 1,287 | 2,921.00 | 396.7 | 346.5 | 400.4 | 141.6 | 321.3 | 155.1 | 135.4 | 156.5 | 55.3 | 125.58 |
| Muddler | | 111 | 48 | 53 | 84 | 74.00 | 5,550.0 | 2,400.0 | 2,650.0 | 4,200.0 | 3,700.0 | 2,187.0 | 946.0 | 1,044.0 | 1,655.0 | 1,458.00 |
| | Total weight | 380 | 175 | 197 | 148 | 225.00 | 41.8 | 19.3 | 21.7 | 16.3 | 24.8 | 16.3 | 7.5 | 8.5 | 6.4 | 9.68 |
| Black-nosed dace | | 1 | .. | 7 | 19 | 6.75 | 50.0 | .... | 350.0 | 950.0 | 337.5 | 20.0 | .... | 138.0 | 374.0 | 133.00 |
| | Total weight | 1 | | 3 | 12 | 4.00 | 0.1 | .... | 0.3 | 1.3 | 0.4 | 0.0 | .... | 0.1 | 0.5 | 0.16 |
| Stickleback | | .. | 1 | .. | 1 | 0.50 | .... | 50.0 | .... | 50.0 | 0.3 | .... | 20.0 | .... | 20.0 | 10.00 |
| | Total weight | .. | 1 | .. | 1 | 0.38 | .... | 0.1 | .... | 0.1 | 0.0 | .... | 0.0 | .... | 0.0 | 0.02 |
| Perch | | .. | .. | .. | 1 | 0.25 | .... | .... | .... | 50.0 | 12.5 | .... | .... | .... | 20.0 | 5.00 |
| | Total weight | .. | .. | .. | 1 | 0.25 | .... | .... | .... | 0.1 | 0.0 | .... | .... | .... | 0.0 | 0.01 |
| Golden shiner | | .. | .. | .. | 1 | 0.25 | .... | .... | .... | 50.0 | 12.5 | .... | .... | .... | 20.0 | 5.00 |
| | Total weight | | | | 2 | 0.50 | .... | .... | .... | 0.2 | 0.1 | .... | .... | .... | 0.1 | 0.03 |
| Crayfish | | 5 | 1 | 3 | 2 | 2.75 | 250.0 | 50.0 | 150.0 | 100.0 | 137.5 | 99.0 | 20.0 | 59.0 | 39.0 | 54.25 |
| | Total weight | 83 | 23 | 59 | 56 | | 9.1 | 2.5 | 6.5 | 6.2 | 6.1 | 3.6 | 1.0 | 2.5 | 2.4 | 2.38 |
| Lamprey | | 1 | .. | .. | .. | 0.25 | 50.0 | .... | .... | .... | 12.5 | 20.0 | .... | .... | .... | 5.00 |
| | Total weight | 4 | .. | .. | .. | 1.00 | 0.4 | .... | .... | .... | 0.1 | 0.2 | .... | .... | .... | 0.05 |
| Total number | | 191 | 118 | 131 | 227 | 166.75 | 9,550.0 | 5,900.0 | 6,850.0 | 11,350.0 | 8,412.5 | 3,764.0 | 2,327.0 | 2,580.0 | 4,472.0 | 3,285.75 |
| Total weight | | 4,976 | 4,357 | 4,766 | 2,452 | 4,137.63 | 547.2 | 479.2 | 524.3 | 269.6 | 455.1 | 214.0 | 187.3 | 204.9 | 105.5 | 177.95 |

**TABLE 3. FISH POPULATION IN SOUTH BRANCH OF THE PINE RIVER, MIDDLE CENSUS SECTION**
**(Actual weights are in grams, calculated weights in pounds. Legal trout are 7 inches, total length, or over)**

| Species | | Actual number and weight of fish in section | | | | | Calculated number and weight of fish per mile of stream | | | | | Calculated number and weight of fish per acre of stream | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | June | July | Aug. | Sept. | Mean | June | July | Aug. | Sept. | Mean | June | July | Aug. | Sept. | Mean |
| Brook trout | Legal | 1 | ---- | ---- | ---- | 0.25 | 56.0 | | ... | ---- | 14.00 | 26.0 | ---- | ---- | ---- | 6.50 |
| | Sub-legal | 15 | 5 | 3.0 | 6 | 7.25 | 723.0 | 278.0 | 167.0 | 334.0 | 375.50 | 342.0 | 132.0 | 79.0 | 158.0 | 177.75 |
| | Total weight | 290 | 132 | 63.0 | 54 | 134.75 | 35.7 | 16.2 | 7.7 | 6.6 | 16.55 | 16.8 | 7.7 | 3.6 | 3.1 | 7.80 |
| Rainbow trout | Legal | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| | Sub-legal | 10 | 61 | 6.0 | 11 | 22.00 | 667.0 | 3,392.0 | 334.0 | 612.0 | 1,251.25 | 316.0 | 1,604.0 | 158.0 | 289.0 | 591.75 |
| | Total weight | 192 | 45 | 17.5 | 72 | 81.63 | 23.6 | 5.5 | 2.2 | 8.9 | 10.05 | 11.1 | 2.6 | 1.1 | 4.2 | 4.75 |
| Common sucker | | 1 | ---- | 1.0 | ---- | 0.50 | 56.0 | ---- | 56.0 | ---- | 28.00 | 26.0 | ---- | 26.0 | ---- | 13.00 |
| | Total weight | 2 | ---- | 1.0 | ---- | 0.75 | 0.2 | | 0.1 | ---- | 0.08 | 0.1 | ---- | 0.1 | ---- | 0.04 |
| Muddler | | [1]49 | 13 | 43.0 | 25 | 32.50 | 2,780.0 | 723.0 | 2,391.0 | 1,390.0 | 1,821.00 | 1,289.0 | 342.0 | 1,130.0 | 658.0 | 854.75 |
| | Total weight | 175 | 40 | 49.0 | 42 | 76.50 | 21.5 | 4.9 | 6.0 | 5.2 | 9.40 | 10.1 | 2.3 | 2.8 | 2.4 | 4.40 |
| Mud minnow | | ---- | 1 | ---- | ---- | 0.25 | ---- | 56.0 | ---- | ---- | 14.00 | ---- | 26.0 | ---- | ---- | 6.50 |
| | Total weight | ---- | 3 | ---- | ---- | 0.75 | ---- | 0.4 | ---- | ---- | 0.10 | ---- | 0.2 | ---- | ---- | 0.05 |
| Lamprey | | 1 | ---- | ---- | ---- | 0.25 | 56.0 | ---- | ---- | ---- | 14.00 | 26.0 | ---- | ---- | ---- | 6.50 |
| | Total weight | 5 | ---- | ---- | ---- | 1.25 | 0.6 | ---- | ---- | ---- | 0.15 | 0.3 | ---- | ---- | ---- | 0.03 |
| Crayfish | | 3 | ---- | 2.0 | ---- | 1.25 | 167.0 | ---- | 111.0 | ---- | 69.50 | 79.0 | ---- | 53.0 | ---- | 33.00 |
| | Total weight | 80 | ---- | 50.0 | ---- | 32.50 | 9.8 | ---- | 6.2 | ---- | 4.00 | 4.6 | ---- | 2.9 | ---- | 1.88 |
| Total number | | 80 | 80 | 55.0 | [2]42 | 64.25 | 4,455.0 | 4,449.0 | 3,059.0 | [3]2,503.0 | 3,616.50 | 2,104.0 | 2,104.0 | 1,446.0 | [3]1,184.0 | 1,709.50 |
| Total weight | | 744 | 220 | 180.5 | 168 | 328.13 | 91.4 | 27.0 | 22.2 | 20.7 | 40.33 | 43.0 | 12.8 | 10.5 | 9.7 | 18.99 |

[1]One muddler escaped; not included in weight.
[2]Three black-nosed dace, too small to weigh, not included.
[3]167 black-nosed dace included in population calculation but not in weight calculation.

**TABLE 4. FISH POPULATION IN SOUTH BRANCH OF THE PINE RIVER, UPPER CENSUS SECTION**
**(Actual weights are in grams, calculated weights in pounds. Legal trout are 7 inches, total length, or over)**

| Species | | Actual number and weight of fish in section | | | | | Calculated number and weight of fish per mile of stream | | | | | Calculated number and weight of fish per acre of stream | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | June | July | Aug. | Sept. | Mean | June | July | Aug. | Sept. | Mean | June | July | Aug. | Sept. | Mean |
| Brook trout | Legal | 1 | ---- | ---- | 2 | 0.75 | 56.0 | ---- | ---- | 111.0 | 41.75 | 18.0 | ---- | ---- | 36.0 | 13.50 |
| | Sub-legal | 8 | 12 | 19 | 27 | 16.50 | 445.0 | 723.0 | 1,056.0 | 1,501.0 | 931.25 | 142.0 | 214.0 | 338.0 | 481.0 | 293.75 |
| | Total weight | 248 | 73 | 180 | 322 | 205.75 | 30.5 | 9.0 | 22.1 | 45.1 | 26.68 | 9.7 | 2.8 | 7.0 | 14.5 | 8.50 |
| Rainbow trout | Legal | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| | Sub-legal | 3 | 19 | 22 | 21 | 16.25 | 167.0 | 1,056.0 | 1,223.0 | 1,167.0 | 903.25 | 53.0 | 338.0 | 392.0 | 374.0 | 289.25 |
| | Total weight | 29 | 23 | 96 | 175 | 80.75 | 3.6 | 2.8 | 11.8 | 21.5 | 9.93 | 1.1 | 0.9 | 3.7 | 6.8 | 3.13 |
| Common sucker | | ---- | ---- | 2 | 33 | 8.75 | ---- | ---- | 111.0 | 1,835.0 | 486.50 | ---- | ---- | 36.0 | 587.0 | 155.75 |
| | Total weight | ---- | ---- | 1 | 319 | 80.00 | ---- | ---- | 0.1 | 39.2 | 9.83 | ---- | ---- | 0.1 | 12.4 | 3.13 |
| Muddler | | 43 | 11 | 20 | 46 | 30.00 | 2,391.0 | 612.0 | 1,112.0 | 2,558.0 | 1,668.25 | 765.0 | 196.0 | 356.0 | 819.0 | 534.00 |
| | Total weight | 150 | 22 | 106 | 146 | 106.00 | 18.5 | 2.7 | 13.0 | 18.0 | 13.05 | 5.8 | 0.9 | 4.1 | 5.7 | 4.13 |
| Black-nosed dace | | ---- | ---- | ---- | 1 | 0.25 | ---- | ---- | ---- | 56.0 | 14.00 | ---- | ---- | ---- | 18.0 | 4.50 |
| | Total weight | ---- | ---- | ---- | 2 | 0.50 | ---- | ---- | ---- | 0.3 | 0.08 | ---- | ---- | ---- | 0.1 | 0.03 |
| Mud minnow | | 1 | ---- | ---- | ---- | 0.25 | 56.0 | ---- | ---- | ---- | 14.00 | 18.0 | ---- | ---- | ---- | 4.50 |
| | Total weight | 4 | ---- | ---- | ---- | 1.00 | 0.5 | ---- | ---- | ---- | 0.13 | 0.2 | ---- | ---- | ---- | 0.05 |
| Bullhead | | 1 | ---- | ---- | ---- | 0.25 | 56.0 | ---- | ---- | ---- | 14.00 | 18.0 | ---- | ---- | ---- | 4.50 |
| | Total weight | 24 | ---- | ---- | ---- | 6.00 | 2.9 | ---- | ---- | ---- | 0.73 | 0.9 | ---- | ---- | ---- | 0.23 |
| Perch | | ---- | ---- | ---- | 1 | 0.25 | ---- | ---- | ---- | 56.0 | 14.00 | ---- | ---- | ---- | 18.0 | 4.50 |
| | Total weight | ---- | ---- | ---- | 1 | 0.25 | ---- | ---- | ---- | 0.1 | 0.03 | ---- | ---- | ---- | 0.0 | 0.01 |
| Crayfish | | 5 | 2 | 6 | 5 | 4.50 | 278.0 | 111.0 | 334.0 | 278.0 | 250.25 | 89.0 | 36.0 | 107.0 | 89.0 | 80.25 |
| | Total weight | 86 | 23 | 126 | 87 | 80.50 | 10.5 | 2.8 | 15.5 | 10.7 | 9.88 | 3.3 | 0.9 | 4.9 | 3.4 | 3.13 |
| Total number | | 62 | 44 | 69 | 136 | 77.75 | 3,449.0 | 2,502.0 | 3,836.0 | 7,562.0 | 4,337.25 | 1,103.0 | 784.0 | 1,229.0 | 2,422.0 | 1,384.50 |
| Total weight | | 541 | 141 | 509 | 1,052 | 560.75 | 66.5 | 17.3 | 62.5 | 134.7 | 70.25 | 21.0 | 5.5 | 19.9 | 42.9 | 22.34 |

TABLE 5. FISH POPULATION IN LITTLE MANISTEE RIVER, MIDDLE CENSUS SECTION
(Actual weights are in grams, calculated weights in pounds. Legal trout are 7 inches, total length, or over)

| Species | | Actual number and weight of fish in section | | | | | Calculated number and weight of fish per mile of stream | | | | | Calculated number and weight of fish per acre of stream | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | June | July | Aug. | Sept. | Mean | June | July | Aug. | Sept. | Mean | June | July | Aug. | Sept. | Mean |
| Brook trout | Legal | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| | Sub-legal | 10.0 | 8 | 3 | 3.0 | 6.00 | 345.0 | 276.0 | 104.0 | 104.0 | 207.25 | 83.0 | 66.0 | 25.0 | 25.0 | 49.75 |
| | Total weight | 88.5 | 104 | 19 | 26.0 | 59.38 | 6.7 | 7.9 | 1.4 | 2.0 | 4.50 | 1.6 | 1.9 | 0.3 | 0.5 | 1.08 |
| Brown trout | Legal | 3.0 | 3 | ---- | ---- | 1.50 | 104.0 | 104.0 | ---- | ---- | 52.00 | 25.0 | 25.0 | ---- | ---- | 12.50 |
| | Sub-legal | 25.0 | 60 | 16 | 3.0 | 26.00 | 863.0 | 2,070.0 | 552.0 | 104.0 | 897.25 | 208.0 | 500.0 | 133.0 | 25.0 | 216.50 |
| | Total weight | 511.0 | 693 | 194 | 45.0 | 360.75 | 38.8 | 52.7 | 14.7 | 3.4 | 2.74 | 9.2 | 12.5 | 3.5 | 0.8 | 6.50 |
| Rainbow trout | Legal | 1.0 | 3 | 4 | ---- | 2.00 | 35.0 | 104.0 | 138.0 | ---- | 69.25 | 8.0 | 25.0 | 33.0 | ---- | 16.50 |
| | Sub-legal | 205.0 | 240 | 283 | 111.0 | 209.75 | 7,073.0 | 8,280.0 | 9,763.0 | 3,795.0 | 7,227.75 | 1,702.0 | 1,992.0 | 2,349.0 | 921.0 | 1,741.00 |
| | Total weight | 2,157.0 | 890 | 1,320 | 669.0 | 1,259.00 | 163.9 | 67.6 | 100.3 | 50.8 | 95.65 | 38.8 | 16.0 | 23.8 | 12.0 | 22.65 |
| Muddler | | 41.0 | 76 | 118 | 89.0 | 81.00 | 1,415.0 | 2,622.0 | 4,071.0 | 3,070.0 | 2,794.50 | 340.0 | 631.0 | 979.0 | 739.0 | 672.25 |
| | Total weight | 43.5 | 56 | 114 | 152.0 | 91.38 | 3.3 | 4.3 | 8.7 | 11.5 | 6.95 | 0.8 | 1.0 | 2.0 | 2.7 | 1.63 |
| Common sucker | | ---- | 42 | 53 | 13.0 | 27.00 | ---- | 1,449.0 | 1,829.0 | 449.0 | 931.75 | ---- | 349.0 | 440.0 | 50.0 | 209.75 |
| | Total weight | ---- | 12 | 59 | 24.0 | 23.75 | ---- | 0.9 | 4.5 | 1.8 | 1.80 | ---- | 0.2 | 1.1 | 0.4 | 0.43 |
| Black-nosed dace | | 40.0 | 27 | 102 | 6.0 | 43.75 | 1,380.0 | 933.0 | 3,519.0 | 207.0 | 1,509.75 | 332.0 | 224.0 | 847.0 | 108.0 | 377.75 |
| | Total weight | 36.0 | 22 | 40 | 3.0 | 25.25 | 2.7 | 1.7 | 3.0 | 0.2 | 1.90 | 0.6 | 0.4 | 0.7 | 0.1 | 0.45 |
| Johnny darter | | ---- | 3 | 2 | 1.0 | 1.50 | ---- | 104.0 | 69.0 | 35.0 | 52.00 | ---- | 25.0 | 17.0 | 8.0 | 12.50 |
| | Total weight | ---- | 7 | 3 | 0.5 | 2.63 | ---- | 0.5 | 0.2 | 0.0 | 0.19 | ---- | 0.1 | ---- | ---- | 0.03 |
| Creek chub | | ---- | ---- | ---- | 1.0 | 0.25 | ---- | ---- | ---- | 35.0 | 8.75 | ---- | ---- | ---- | 8.0 | 2.00 |
| | Total weight | ---- | ---- | ---- | 0.5 | 0.13 | ---- | ---- | ---- | 0.0 | 0.01 | ---- | ---- | ---- | ---- | ---- |
| Lamprey | | 1.0 | 15 | 2 | ---- | 4.50 | 35.0 | 517.0 | 69.0 | ---- | 155.25 | 8.0 | 125.0 | 17.0 | ---- | 37.50 |
| | Total weight | 5.0 | 40 | 2 | ---- | 11.75 | 0.4 | 3.0 | 0.1 | ---- | 0.20 | 0.1 | 0.7 | ---- | ---- | 0.20 |
| Crayfish | | 3.0 | 9 | 27 | 4.0 | 10.75 | 104.0 | 310.0 | 934.0 | 138.0 | 371.50 | 25.0 | 75.0 | 224.0 | 33.0 | 89.25 |
| | Total weight | 17.0 | 26 | 34 | 3.0 | 20.00 | 1.3 | 2.0 | 2.6 | 0.2 | 1.53 | 0.3 | 0.5 | 0.6 | 0.1 | 0.38 |
| Total number | | 329.0 | 486 | 610 | 231.0 | 414.00 | 11,354.0 | 16,769.0 | 21,048.0 | 7,937.0 | 14,277.00 | 2,731.0 | 4,037.0 | 5,064.0 | 1,917.0 | 3,437.25 |
| Total weight | | 2,858.0 | 1,850 | 1,785 | 923.0 | 1,854.00 | 217.1 | 140.6 | 135.5 | 70.0 | 140.80 | 51.4 | 33.3 | 32.0 | 16.6 | 33.33 |

**TABLE 6. FISH POPULATION IN LITTLE MANISTEE RIVER, UPPER CENSUS SECTION**
**(Actual weights are in grams, calculated weights in pounds. Legal trout are 7 inches, total length, or over)**

| Species | | Actual number and weight of fish in section | | | | | Calculated number and weight of fish per mile of stream | | | | | Calculated number and weight of fish per acre of stream | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | June | July | Aug. | Sept.[1] | Mean | June | July | Aug. | Sept. | Mean | June | July | Aug. | Sept. | Mean |
| Brook trout | Legal | -- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| | Sub-legal | 1 | 3 | [2]2 | 2 | 2.00 | 50.0 | 150.0 | 100.0 | 100.0 | 100.00 | 15.0 | 46.0 | 31.0 | 31.0 | 30.75 |
| | Total weight | 40 | 84 | 37 | 55 | 54.00 | 4.4 | 9.2 | 4.0 | 6.1 | 5.93 | 1.4 | 2.9 | 1.3 | 1.9 | 1.88 |
| Brown trout | Legal | 7 | 7 | 4 | 1 | 4.75 | 350.0 | 350.0 | 200.0 | 50.0 | 237.50 | 108.0 | 108.0 | 62.0 | 15.0 | 73.25 |
| | Sub-legal | 8 | 9 | 6 | 6 | 7.75 | 400.0 | 450.0 | 300.0 | 300.0 | 362.50 | 123.0 | 139.0 | 92.0 | 92.0 | 111.50 |
| | Total weight | 874 | 656 | 301 | 182 | 502.60 | 96.1 | 72.2 | 33.0 | 20.0 | 55.33 | 29.7 | 22.3 | 10.2 | 6.2 | 17.10 |
| Rainbow trout | Legal | 1 | 4 | 5 | 1 | 2.75 | 50.0 | 200.0 | 250.0 | 50.0 | 137.50 | 15.0 | 62.0 | 77.0 | 15.0 | 42.25 |
| | Sub-legal | 16 | 24 | 9 | 5 | 13.50 | 800.0 | 1,200.0 | 450.0 | 250.0 | 675.00 | 246.0 | 370.0 | 139.0 | 77.0 | 208.00 |
| | Total weight | 624 | 636 | 489 | 97 | 461.50 | 68.6 | 70.0 | 53.9 | 10.7 | 50.80 | 21.2 | 21.6 | 16.6 | 3.3 | 15.63 |
| Common sucker | | 6 | 27 | 7 | 9 | 12.25 | 300.0 | 1,350.0 | 350.0 | 450.0 | 612.50 | 92.0 | 416.0 | 108.0 | 139.0 | 188.75 |
| | Total weight | 739 | 4 | 465 | 480 | 422.00 | 81.3 | 0.4 | 51.2 | 52.8 | 46.43 | 25.1 | 0.1 | 15.8 | 16.3 | 14.33 |
| Muddler | | 14 | 49 | 34 | 63 | 40.00 | 700.0 | 2,450.0 | 1,700.0 | 3,150.0 | 2,000.00 | 216.0 | 755.0 | 524.0 | 970.0 | 616.25 |
| | Total weight | 30 | 65 | 17 | 109 | 55.25 | 3.3 | 7.2 | 1.8 | 12.0 | 6.75 | 1.0 | 2.2 | 0.6 | 3.7 | 1.88 |
| Black-nosed dace | | 14 | 69 | 19 | 23 | 31.25 | 700.0 | 3,450.0 | 950.0 | 1,150.0 | 1,562.50 | 216.0 | 1,063.0 | 293.0 | 354.0 | 431.50 |
| | Total weight | 1 | 12 | 5 | 13 | 7.63 | 0.1 | 1.3 | 0.6 | 1.4 | 0.84 | ---- | 0.4 | 0.2 | 0.4 | 0.25 |
| Johnny darter | | ---- | 1 | ---- | ---- | 0.25 | ---- | 50.0 | ---- | ---- | 12.50 | ---- | 15.0 | ---- | ---- | 3.75 |
| | Total weight | ---- | 2 | ---- | ---- | 0.50 | ---- | 0.2 | ---- | ---- | 0.05 | ---- | 0.1 | ---- | ---- | 0.03 |
| Creek chub | | ---- | ---- | ---- | 3 | 0.75 | ---- | ---- | ---- | 150.0 | 37.50 | ---- | ---- | ---- | 46.0 | 14.50 |
| | Total weight | ---- | ---- | ---- | 1 | 0.25 | ---- | ---- | ---- | 0.1 | 0.03 | ---- | ---- | ---- | ---- | ---- |
| Stickleback | | ---- | ---- | ---- | 1 | 0.25 | ---- | ---- | ---- | 50.0 | 12.50 | ---- | ---- | ---- | 15.0 | 3.75 |
| | Total weight | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Lamprey | | ---- | 2 | ---- | ---- | 0.50 | ---- | 100.0 | ---- | ---- | 25.00 | ---- | 31.0 | ---- | ---- | 7.75 |
| | Total weight | ---- | 5 | ---- | ---- | 0.80 | ---- | 0.6 | ---- | ---- | 0.15 | ---- | 0.2 | ---- | ---- | 0.05 |
| Crayfish | | 15 | 16 | 16 | 39 | 21.50 | 750.0 | 800.0 | 800.0 | 1,950.0 | 1,075.00 | 231.0 | 246.0 | 246.0 | 601.0 | 331.00 |
| | Total weight | 90 | 53 | 108 | 198 | 112.25 | 9.9 | 5.8 | 11.8 | 21.8 | 12.33 | 3.1 | 1.8 | 3.7 | 6.4 | 3.75 |
| Total number | | 82 | 211 | 102 | 153 | 137.00 | 4,100.0 | 10,550.0 | 5,100.0 | 7,650.0 | 6,850.00 | 1,262.0 | 3,251.0 | 1,572.0 | 2,355.0 | 2,110.00 |
| Total weight | | 2,397 | 1,517 | 1,422 | 1,135 | 1,617.75 | 263.7 | 166.7 | 156.3 | 124.9 | 177.90 | 81.5 | 51.6 | 48.4 | 38.2 | 54.95 |

[1]One sub-legal trout observed but not captured for weighing; not included in calculations.

[2]One of the two sub-legal brook trout escaped before measuring and weighing. Included in population calculation but not in weight calculation.

TABLE 7. FISH POPULATION IN THE NORTH BRANCH OF THE BOARDMAN RIVER, LOWER CENSUS SECTION
(Actual weights are in grams, calculated weights in pounds. Legal trout are 7 inches, total length, or over)

| Species | | Actual number and weight of fish in section | | | | Calculated number and weight of fish per mile of stream | | | | Calculated number and weight of fish per acre of stream | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | July 1 | July 22 | August | Mean | July 1 | July 22 | August | Mean | July 1 | July 22 | August | Mean |
| Brook trout | Legal | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| | Sub-legal | 3.0 | 3 | 1 | 2.33 | 131.0 | 131.0 | 44.0 | 102.00 | 36.0 | 24.0 | 12.0 | 24.00 |
| | Total weight | 3.5 | 6 | 1 | 3.50 | 0.3 | 0.6 | 0.1 | 0.33 | 0.9 | 0.1 | 0.0 | 0.43 |
| Brown trout | Legal | [1]1.0 | 1 | ---- | 0.67 | [1]44.0 | 44.0 | ---- | 29.33 | [1]12.0 | 12.0 | ---- | 8.00 |
| | Sub-legal | ---- | [2]1 | 6 | 2.33 | ---- | [2]44.0 | 261.0 | 101.67 | ---- | [2]12.0 | 72.0 | 28.00 |
| | Total weight | ---- | 66 | 41 | 35.67 | ---- | 6.3 | 3.9 | 3.40 | ---- | 1.7 | 1.1 | 0.93 |
| Common sucker | | 2.0 | 14 | 11 | 9.00 | 87.0 | 609.0 | 479.0 | 391.67 | 24.0 | 168.0 | 132.0 | 108.00 |
| | Total weight | 1.0 | 8 | 15 | 8.00 | 0.1 | 0.8 | 1.4 | 0.77 | ---- | 0.2 | 0.4 | 0.30 |
| Muddler | | 7.0 | 72 | 138 | 72.33 | 305.0 | 3,132.0 | 6,003.0 | 3,146.67 | 84.0 | 864.0 | 1,656.0 | 868.00 |
| | Total weight | 13.0 | 26 | 71 | 36.67 | 1.1 | 2.5 | 6.8 | 3.47 | 0.3 | 0.7 | 1.8 | 0.93 |
| Black-nosed dace | | ---- | 16 | ---- | 5.30 | ---- | 696.0 | ---- | 232.00 | ---- | 192.0 | ---- | 64.00 |
| | Total weight | ---- | 3 | ---- | 1.00 | ---- | 0.3 | ---- | 0.10 | ---- | 0.1 | ---- | 0.03 |
| Creek chub | | ---- | ---- | 26 | 8.67 | ---- | ---- | 1,131.0 | 377.00 | ---- | ---- | 312.0 | 104.00 |
| | Total weight | ---- | ---- | 9 | 3.00 | ---- | ---- | 0.9 | 0.30 | ---- | ---- | 0.2 | 0.06 |
| Crayfish | | 10.0 | 26 | 74 | 36.67 | 435.0 | 2,439.0 | 3,219.0 | 2,031.00 | 120.0 | 312.0 | 888.0 | 400.00 |
| | Total weight | 31.0 | 37 | 110 | 59.33 | 1.0 | 6.0 | 10.6 | 5.87 | 0.8 | 1.0 | 2.9 | 1.30 |
| Total number | | [1]23.0 | [2]133 | 256 | 137.33 | 1,002.0 | 7,095.0 | 11,137.0 | 6,411.33 | 276.0 | 1,584.0 | 3,072.0 | 1,644.00 |
| Total weight | | 48.5 | 146 | 247 | 147.00 | 2.5 | 16.5 | 23.7 | 14.23 | 2.0 | 3.8 | 6.4 | 4.09 |

[1]One legal brown trout observed but not captured forms the basis for this calculation.

[2]One sub-legal trout (species ?) observed but not captured included in population calculations but not in weight calculations.

**TABLE 8. FISH POPULATION IN THE NORTH BRANCH OF THE BOARDMAN RIVER, MIDDLE CENSUS SECTION**

**(Actual weights are in grams, calculated weights in pounds. Legal trout are 7 inches, total length, and over)**

| Species | | Actual number and weight of fish in section | | | | Calculated number and weight of fish per mile of stream | | | | Calculated number and weight of fish per acre of stream | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | July 1 | July 23 | August | Mean | July 1 | July 23 | August | Mean | July 1 | July 23 | August | Mean |
| Brook trout | Legal | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| | Sub-legal | 3 | 4 | 2.0 | 3.00 | 167.0 | 222.0 | 111.0 | 166.67 | 48.0 | 64.0 | 32.0 | 48.00 |
| | Total weight | 10 | 9 | 11.0 | 10.00 | 1.2 | 1.1 | 1.3 | 1.20 | 0.4 | 0.3 | 0.4 | 0.37 |
| Brown trout | Legal | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| | Sub-legal | 6 | 2 | 2.0 | 3.33 | 334.0 | 111.0 | 111.0 | 185.30 | 96.0 | 32.0 | 32.0 | 53.33 |
| | Total weight | 79 | 3 | 12.0 | 31.30 | 9.7 | 0.4 | 1.5 | 3.87 | 2.8 | 0.1 | 0.4 | 1.17 |
| Muddler | | 19 | 44 | 119.0 | 60.67 | 1,056.0 | 2,446.0 | 6,616.0 | 3,372.67 | 306.0 | 708.0 | 1,916.0 | 976.67 |
| | Total weight | 61 | 20 | 79.0 | 53.33 | 7.5 | 2.5 | 9.7 | 6.56 | 2.1 | 0.7 | 2.8 | 1.87 |
| Common sucker | | ---- | 5 | 11.0 | 5.33 | ---- | 278.0 | 612.0 | 29.67 | ---- | 81.0 | 177.0 | 86.00 |
| | Total weight | ---- | ---- | 15.0 | 5.00 | ---- | 0.1 | 1.8 | 0.63 | ---- | ---- | 0.5 | 0.17 |
| Black-nosed dace | | ---- | 2 | 6.0 | 2.67 | ---- | 111.0 | 334.0 | 148.33 | ---- | 32.0 | 97.0 | 43.00 |
| | Total weight | ---- | 1 | 0.5 | 0.50 | ---- | 0.1 | 0.1 | 0.07 | ---- | ---- | ---- | ---- |
| Creek chub | | ---- | 18 | 101.0 | 39.67 | ---- | 1,000.0 | 5,616.0 | 2,205.33 | ---- | 290.0 | 1,626.0 | 638.67 |
| | Total weight | ---- | 4 | 34.5 | 12.83 | ---- | 0.4 | 4.2 | 1.53 | ---- | 0.1 | 1.2 | 0.43 |
| Crayfish | | 13 | 14 | 22.0 | 16.33 | 723.0 | 778.0 | 1,223.0 | 908.00 | 209.0 | 225.0 | 354.0 | 193.00 |
| | Total weight | 51 | 29 | 34.0 | 38.00 | 6.3 | 3.7 | 4.2 | 3.73 | 1.8 | 1.0 | 1.2 | 0.73 |
| Total number | | 41 | 89 | 263.0 | 131.00 | 2,280.0 | 4,946.0 | 14,623.0 | 7,283.0 | 659.0 | 1,432.0 | 4,234.0 | 2,108.30 |
| Total weight | | 201 | 66 | 186.0 | 151.00 | 24.7 | 8.3 | 22.8 | 18.6 | 7.1 | 2.2 | 6.5 | 5.29 |

TABLE 9. FISH POPULATION IN THE NORTH BRANCH OF THE BOARDMAN RIVER, UPPER CENSUS SECTION

(Actual weights are in grams, calculated weights in pounds. Legal trout are 7 inches, total length, and over)

| Species | | Actual number and weight of fish in section | | | Calculated number and weight of fish per mile of stream | | | Calculated number and weight of fish per acre of stream | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | July | August | Mean | July | August | Mean | July | August | Mean |
| Brook trout | Legal | .... | .... | — | .... | .... | .... | .... | .... | .... |
| | Sub-legal | 1 | 1 | 1.0 | 39.0 | 39.0 | 39.00 | 15.0 | 15.0 | 15.00 |
| | Total weight | 2 | 11 | 6.5 | 0.2 | 0.9 | 0.55 | 0.1 | 0.4 | 0.25 |
| Brown trout | Legal | [1]1 | .... | 1.0 | [1]78.0 | .... | 39.00 | [1]29.0 | .... | 14.50 |
| | Sub-legal | [1]27 | 18 | 23.0 | [1]1,117.0 | 693.0 | 905.00 | [1]412.0 | 265.0 | 338.50 |
| | Total weight | 368 | 99 | 233.5 | [2]31.3 | 8.4 | 19.70 | [2]11.8 | 3.2 | 7.50 |
| Common sucker | | 7 | 11 | 9.0 | 270.0 | 424.0 | 347.00 | 103.0 | 162.0 | 132.50 |
| | Total weight | 3 | 15 | 9.0 | 0.2 | 1.3 | 0.75 | 0.1 | 0.5 | 0.30 |
| Muddler | | 18 | 65 | 41.5 | 693.0 | 2,503.0 | 1,598.00 | 265.0 | 956.0 | 610.50 |
| | Total weight | 34 | 50 | 42.0 | 2.9 | 4.2 | 3.55 | 1.1 | 1.6 | 1.35 |
| Black-nosed dace | | 5 | 42 | 23.5 | 193.0 | 1,617.0 | 905.00 | 74.0 | 617.0 | 345.50 |
| | Total weight | 1 | 15 | 8.0 | 0.1 | 1.3 | 0.70 | 0.0 | 0.5 | 0.26 |
| Creek chub | | .... | 49 | 24.5 | .... | 1,887.0 | 943.50 | .... | 720.0 | 360.00 |
| | Total weight | .... | 15 | 7.5 | .... | 1.3 | 0.65 | .... | 0.5 | 0.25 |
| Bluegill | | .... | 1 | 0.5 | .... | 39.0 | 17.50 | .... | 15.0 | 7.50 |
| | Total weight | .... | 5 | 2.5 | .... | 0.4 | 0.20 | .... | 0.2 | 0.10 |
| Crayfish | | 7 | 18 | 12.5 | 270.0 | 693.0 | 481.50 | 103.0 | 265.0 | 184.00 |
| | Total weight | 44 | 26 | 35.0 | 3.7 | 2.2 | 2.95 | 1.4 | 0.8 | 1.10 |
| Total number | | 66 ([1]68) | 205 | 136.5 | 2,660.0 | 7,895.0 | 5,277.50 | 1,001.0 | 3,015.0 | 2,008.00 |
| Total weight | | 452 | 236 | 344.0 | 38.4 | 20.0 | 29.20 | 14.5 | 7.7 | 11.1 |

[1]One legal and one sub-legal brown trout escaped, but were included in calculations of the population.

[2]Calculated pounds for twenty-eight brown trout weighed. Does not include estimated pounds of escaped fish.

section. The computations of the number of fish and weight per acre provide the best figures for comparing population densities in different sections of the same stream and other streams.

No calculations of populations have been made for entire streams on the basis of the sections sampled as in most instances the censuses were conducted in portions of streams representing only particular trout habitats which could be studied by this method. Reliable estimates of the population of entire streams cannot be computed unless the proportionate areas of the various types of habitat studied in the entire stream are accurately known. The calculations per mile and per acre are representative only of the particular habitats studied, and even these figures must be considered tentative because of the extreme variation encountered in similar environments during different months (Tables 2 to 9).

To determine what relationship, if any, exists between the trout-stream habitat and the calculated population of fish per acre, the salient habitat characteristics of the various sections are given in Table 10 together with the average number of fish and calculated average weight of fish per acre. A numerical rating by means of index numbers has also been used in the table to facilitate comparisons. According to the available data, the most productive stream, in pounds per acre of fish and number of trout, is the Little Manistee, followed by the South Branch of the Pine. The North Branch of the Boardman was poorest in calculated numbers, pounds of fish, and pounds of trout per acre. The Little Manistee River was also the best from the fisherman's standpoint, since it produced more legal trout per acre than the South Branch of the Pine or the North Branch of the Boardman. One section of the latter stream yielded no legal trout at any time during the investigations.

The most productive sections were those which, according to former standards, had a relatively unproductive type of bottom—chiefly sand. Those sampled areas with a bottom consisting predominantly of gravel were comparatively low in fish production (Table 10). A greater average depth was the one characteristic common to the three most productive of the eight sections. The depth of those three sections (lower, South Branch of the Pine; upper and middle, Little Manistee) averaged from 14 to 18 inches, while the remainder averaged from 9 to 11 inches in depth. Depth of the water may be an important limiting factor in the determination of the carrying capacity of a stream. A greater average depth was the only favorable habitat characteristic of two sections of the little Manistee River, both of which led, in general, in the production of trout and other fish.

## Stability of Fish Populations

Some measure of the extent to which the fish of the sections investigated remain in the same area or migrate may be calculated

**TABLE 10. RELATION OF CERTAIN ENVIRONMENTAL CHARACTERISTICS AND CALCULATED AVERAGE NUMBERS AND POUNDS OF FISH PER ACRE**

(Numerical order of data as indicated by index numbers in parentheses was determined from Tables 1 to 9, inclusive.)

| Stream | Section | Average depth (inches) | Shade | Submerged cover | No. lbs. of all fish | No. lbs. of trout | Per cent of trout | No. of trout | No. of legal trout | Dominant bottom type[1] |
|---|---|---|---|---|---|---|---|---|---|---|
| South Branch of Pine | Upper | 9.8 (7) | Partly | Excellent | 22 (4) | 11.0 (5) | 43.0 (2) | 597 (3) | 13 (7) | Gravel |
| | Middle | 10.9 (5) | Densely | Excellent | 19 (5) | 12.5 (4) | 42.5 (3) | 776 (2) | 20 (4) | Clay |
| | Lower | 13.7 (3) | Partly | Excellent | 178 (1) | 40.0 (1) | 13.6 (6) | 448 (5) | 100 (2) | Muck & detritus |
| Little Manistee | Upper | 17.2 (2) | Partly | Average | 55 (2) | 35.0 (2) | 24.5 (5) | 466 (4) | 115 (1) | Sand |
| | Middle | 17.4 (1) | Exposed | Poor | 33 (3) | 30.0 (3) | 60.0 (1) | 2,036 (1) | 29 (3) | Sand |
| North Branch of Boardman | Upper | 10.1 (6) | Partly | Excellent | 11 (6) | 8.0 (6) | 27.3 (4) | 30 (8) | 15 (5) | Gravel |
| | Middle | 11.4 (4) | Exposed | Poor | 5 (7) | 1.6 (8) | 9.0 (8) | 101 (6) | 0 (8) | Sand |
| | Lower | 9.1 (8) | Partly | Poor | 4 (8) | 1.4 (7) | 11.5 (7) | 60 (7) | 8 (7) | Sand |

[1]Fifty per cent or more.

from the recaptures of fish marked during the course of the work. All fish seined in both upper and lower census sections of the South Branch of the Pine River and the North Branch of the Boardman River were fin-clipped and released after all pertinent data had been recorded. This procedure was also followed in the upper section of the Little Manistee River. A different fin was removed each month (except in marking the muddlers); thus in succeeding months fish which had been captured previously were distinguished readily from more recent inhabitants of the census section.

An analysis of the recaptures of marked fish has been made by considering the total number of trout (all species combined in order to obtain a sufficient number of individuals), suckers, and muddlers, in the stream sections where recaptures were made. The percentages of marked fish that remained from month to month in the section are shown in the horizontal rows of Tables 11 to 13, and were calculated from the number of fish recovered bearing the characteristic marks of the preceding months. The net percentage loss (which may have been due to migration, to capture by fishermen, to predation or to other causes) is calculated by subtracting the total number of marked fish recovered in any month from the number of marked fish released during the previous month, and dividing the result by the number of fish released in that month.

The net percentage loss of the trout population from month to month may vary from 44 to 94 per cent (Table 11). The suckers

**TABLE 11. PERCENTAGE OF TROUT POPULATION REMAINING IN OR RETURNING TO CENSUS SECTIONS FROM MONTH TO MONTH IN TWO STREAMS**

**(Numbers of marked fish recovered are indicated in parentheses)**

| Month marked | Total number of trout in section in month | Number of unmarked trout in section in month | Percentage of marked trout recovered in month | | |
|---|---|---|---|---|---|
| | | | July | August | September |
| **South Branch of Pine River, Lower Census Section** | | | | | |
| June | 17[1] | 17[1] | 53.0 (9) | 18.1 (4) | 13.6 (3) |
| July | 24 | 15 | ----- | 20.0 (3) | 13.3 (2) |
| August | 18 | 11 | ----- | ----- | 27.3 (3) |
| September | 33 | 25 | ----- | ----- | ----- |
| Net percentage loss of marked trout | | | 47.0 (9) | 70.8 (7) | 55.6 (8) |
| **South Branch of Pine River, Upper Census Section** | | | | | |
| June | 12 | 12 | 8.3 (1) | 16.7 (2) | 0.0 (0) |
| July | 31 | 30 | ----- | 0.0 (0) | 3.3 (1) |
| August | 41 | 39 | ----- | ----- | 28.2 (11) |
| September | 50 | 38 | ----- | ----- | ----- |
| Net percentage loss of marked trout | | | 91.7 (1) | 93.6 (2) | 70.7 (12) |
| **Little Manistee River, Upper Census Section** | | | | | |
| June | 33 | 33 | 33.0 (11) | 18.1 (6) | 6.1 (2) |
| July | 47 | 36 | ----- | 22.2 (8) | 16.7 (6) |
| August | 18 | 12[2] | ----- | ----- | 50.0 (2) |
| September | 15 | 5 | ----- | ----- | ----- |
| Net percentage loss of marked trout | | | 67.0 (11) | 70.2 (14) | 44.4 (10) |

[1]Represents number actually released with fins clipped. Five others escaped.

[2]Eight of these died, leaving four to be added to the total number of marked fish recovered.

(Table 12) and the muddlers (Table 13) suffered a similarly high loss from month to month, varying from 69 to 100 per cent. In the North Branch of the Boardman River and in the Little Manistee River none of the marked minnows or coarse fish was ever recovered in successive months, indicating that a completely new population of minnows and coarse fish had moved in between the dates of sampling. Evidence of minor migrations may be inferred from the results of the monthly removal of the fish from the middle sections of each of the streams. Tables 3, 5 and 8 demonstrate conclusively that these sections were at least partially, if not fully, repopulated within thirty days.

The data definitely suggest that populations of stream fish are relatively unstable in specific areas of a stream during the summer months, and indicate that calculations of stream populations from

**TABLE 12. PERCENTAGE OF SUCKER POPULATION REMAINING IN OR RETURNING TO THE LOWER CENSUS SECTION, SOUTH BRANCH OF THE PINE RIVER, FROM MONTH TO MONTH**

**(Numbers of marked fish recovered are indicated in parentheses)**

| Month marked | Total number of fish in section in month | Number of unmarked fish in section in month | Percentage of marked suckers recovered in month | | |
|---|---|---|---|---|---|
| | | | July | August | September |
| June | 51 | 51 | 21.5 (11) | 17.6 (9) | 1.9 (1) |
| July | 44 | 33 | ...... | 15.1 (5) | 0.0 |
| August | 56 | 44 | ...... | ...... | 0.0 |
| September | 86 | 85 | ...... | ...... | ...... |
| Net percentage loss of marked fish | | | 78.5 (11) | 68.1 (14) | 98.2 (1) |

**TABLE 13. PERCENTAGE OF MUDDLER POPULATION REMAINING IN OR RETURNING TO CENSUS SECTIONS OF THE SOUTH BRANCH OF THE PINE RIVER, FROM MONTH TO MONTH**

**(Numbers of marked fish recovered are indicated in parentheses)**

| Month marked | Total number of fish in section in month | Number of unmarked fish in section in month | Percentage of marked muddlers recovered in month | | |
|---|---|---|---|---|---|
| | | | July | August | September |
| **Lower Census Section** | | | | | |
| June | 111 | 111 | 13.6 (15) | ...... | ...... |
| July | 48 | 33 | ...... | [1]11.8 (17) | ...... |
| August | 53 | 36 | ...... | ...... | ...... |
| September | 84 | 84 | ...... | ...... | ...... |
| Net percentage loss of marked fish | | | 86.4 (15) | 88.2 (17) | 100 |
| **Upper Census Section** | | | | | |
| June | 43 | 43 | 6.0 (3) | ...... | ...... |
| July | 11 | 8 | ...... | [1]7.8 (4) | ...... |
| August | 20 | 16 | ...... | ...... | [1]7.5 (5) |
| September | 46 | 41 | ...... | ...... | ...... |
| Net percentage loss of marked fish | | | 94.0 (3) | 92.2 (4) | 92.5 (5) |

[1]Calculated on the basis of the total number marked up to this month, since muddlers from months after July could not be recognized as they did not have enough fins suitable for clipping.

counts made on one or two short sections of stream at only one period of the year are not reliable.

## Age Groups Represented in Populations

Scale samples were taken from all trout of legal size (7 inches, total length) encountered in the census sections, and from all the smaller trout, except where it was obvious from length measurements that they were in their first summer of life. The trout scales collected during the investigation were cleaned, mounted in a glycerin-gelatin preparation, and examined with a micro-projector.

The results of the age study are presented in Tables 14, 15 and 16, in which the total number of trout of each species in each age group by dates or by months are given for the three streams.

**TABLE 14. TOTAL NUMBER AND AVERAGE TOTAL LENGTH IN MILLIMETERS OF TROUT BY SPECIES IN EACH AGE GROUP IN CENSUS SECTIONS OF THE NORTH BRANCH OF THE BOARDMAN RIVER**

(Figures in parentheses indicate number of legal fish. Legal trout are 178 millimeters in total length and over)

| Dates | Species | Age groups O | | I+ | | II+ | | III+ | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | No. | Average total length | No. | Average total length | No. | Average total length | No. | Total length | Total number |
| July 1, 2 | Brook | 6 | 68.0 | .... | ...... | .... | ...... | ...... | ...... | 6 |
| | Brown | 4 | 61.0 | 2 | 152.5 | .... | ...... | ...... | ...... | 6 |
| July 22, 23 | Brook | 7 | 68.0 | .... | ...... | .... | ...... | ...... | ...... | 7 |
| | Brown | 31 | 76.7 | 2 (2) | 184.5 | .... | ...... | 1 (1) | 279 | 34 (3) |
| Aug. 23, 24 | Brook | 4 | 86.5 | .... | ...... | .... | ...... | ...... | ...... | 4 |
| | Brown | 26 | 84.4 | .... | ...... | .... | ...... | ...... | ...... | 26 |

It appears that the distribution of the age groups of the trout population in the censused portion of the North Branch of the Boardman was somewhat abnormal, since the population consisted almost entirely of brook trout and brown trout of the O-group. The distribution of the age groups of the trout population in the South Branch of the Pine River and in the Little Manistee River were more normal in that the older age groups of trout were more numerous. In the South Branch of the Pine River, although two adult brown trout were taken, no members of the O-group were captured.

Rainbows decidedly dominated the trout population of the Little Manistee, despite the fact that almost 50,000 brown trout, and no rainbow trout, were planted in this area during the last four years.

The rainbows are by far the most numerous trout in the Little Manistee, and make up a major part of the anglers' catch in this stream (Shetter, unpublished report). According to Greeley (1933) a large proportion of the young rainbows descend to Lake Michigan before reaching the legal size of 7 inches. Greeley also reported that

**TABLE 15. TOTAL NUMBER AND AVERAGE TOTAL LENGTH IN MILLIMETERS OF TROUT BY SPECIES IN EACH AGE GROUP BY MONTHS IN CENSUS SECTIONS OF THE SOUTH BRANCH OF THE PINE RIVER**

(Figures in parentheses under "Number" indicate the number of legal fish, and under "Average total length" the number of specimens on which the average length is based where the average does not represent all specimens counted. Legal trout are 178 millimeters in total length and over)

| Month | Species | O No. | O Average total length | I+ No. | I+ Average total length | II+ No. | II+ Average total length | III+ No. | III+ Total length | Total number |
|---|---|---|---|---|---|---|---|---|---|---|
| June | Brook | 9 | 54 | 24 (4) | 156 | 3 (3) | 192 | ---- | ---- | 36 (7) |
| | Brown | ---- | ---- | 1 | 137 | ---- | ---- | ---- | ---- | 1 (0) |
| | Rainbow[1] | 8 | 43 | 12 | 143 | ---- | ---- | ---- | ---- | 20 (0) |
| July | Brook | 13 | 72 | 12 (2) | 149 | 5 (3) | 183 | ---- | ---- | 30 (5) |
| | Brown | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| | Rainbow[2] | 80 | 42 (59) | 6 | 156 | 5 (2) | 169 | ---- | ---- | 91 (2) |
| August | Brook | 18 | 81 | 8 (1) | 153 | ---- | ---- | 1 (1) | 285 | 27 (2) |
| | Brown | ---- | ---- | ---- | ---- | ---- | ---- | 1 (1) | 264 | 1 (1) |
| | Rainbow | 32 | 78 (10) | 6 (1) | 147 | 2 (1) | 177 | ---- | ---- | 40 (2) |
| September | Brook | 31 | 96 | 7 (1) | 160 | 2 (1) | 167 | 1 (1) | 291 | 41 (4) |
| | Brown | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| | Rainbow | 48 | 83 | 8 (2) | 152 | 3 (1) | 174 | ---- | ---- | 59 (3) |

[1]Three sub-legal fish escaped before scales were taken.

[2]Rainbows of age-group O from July collections measured on March 22, 1938, and corrected for shrinkage by a factor of 1.054 as previously determined by Shetter (1936).

**TABLE 16. TOTAL NUMBER AND AVERAGE TOTAL LENGTH IN MILLIMETERS OF TROUT BY SPECIES IN EACH AGE GROUP BY MONTHS IN CENSUS SECTIONS OF THE LITTLE MANISTEE RIVER**

(Figures in parentheses under "Number" indicate the number of legal fish, and under "Average total length" the number of specimens on which the average length is based where the average is not made from all the specimens counted. Legal trout are 178 millimeters in total length and over)

| Month | Species | O No. | O Average total length | I+ No. | I+ Average total length | II+ No. | II+ Average total length | III+ No. | III+ Average total length | Total number |
|---|---|---|---|---|---|---|---|---|---|---|
| June[1] | Brook | 9 | 77 (7) | 2 | 163 | ---- | ---- | ---- | ---- | 11 (0) |
| | Brown[2] | 25 | 71 (23) | 12 (4) | 170 | 3 (3) | 199 | 2 (2) | 220 | 42 (10) |
| | Rainbow | 148 | 38 | 67 (2) | 149 | 6 | 165 | 2 ? | 158 | 223 (2) |
| July | Brook | 7 | 74 | 3 | 168 | ---- | ---- | ---- | ---- | 10 (0) |
| | Brown[3] | 64 | 81 (55) | 10 (6) | 179 | 3 (2) | 186 | ---- | ---- | 77 (10) |
| | Rainbow | 250 | 54 (21) | 25 (6) | 164 | 5 (3) | 182 | ---- | ---- | 280 (9) |
| August | Brook | 4 | 81 (3) | 1 | 164 | ---- | ---- | ---- | ---- | 5 (0) |
| | Brown | 22 | 102 | 3 (3) | 180 | 1 (1) | 200 | ---- | ---- | 26 (4) |
| | Rainbow | 288 | 73 (136 | 8 (4) | 172 | 5 (5) | 191 | ---- | ---- | 301 (9) |
| September | Brook | 4 | 105 | 1 | 168 | ---- | ---- | ---- | ---- | 5 (0) |
| | Brown | 8 | 114 | 2 (1) | 185 | ---- | ---- | ---- | ---- | 10 (1) |
| | Rainbow | 116 | 84 | 1 (1) | 185 | ---- | ---- | ---- | ---- | 117 (1) |

[1]All O-group fish were measured on March 22, 1938, and corrected for shrinkage by a factor of 1.054, as previously determined by Shetter (1936).

[2]One legal brown trout, age not determinable, included in total of legal fish.

[3]Two legal brown trout, age not determinable, included in total of legal fish.

only 26.2 per cent of the age-group I rainbow trout collected from the Little Manistee in August, 1930, attained legal size during their second year of life. If they had migrated to the lake before they became of legal size, none would have been taken by anglers; a small percentage might be taken later during the spawning migration. Migratory habits of the rainbow in the South Branch of the Pine River have not been studied. Because of the migratory habits of the rainbow in the Little Manistee they are not as continuously available to the angler as the non-migratory brook and brown trout.

It was observed that the shallower, shaded sections which had submerged cover generally produced the greatest number of O-group trout. There is little similarity among the streams relative to the proportion of age groups of different species present. However, the relationship between the total numbers in each age group of all species combined in each stream was more constant throughout the investigation. Just what constitutes a normal distribution of age groups in trout populations will be known only when more data of a similar type have been gathered.

## Conclusions

Estimates of the total fish population of a stream, based on a small number of samples obtained by blocking and seining are held to be inaccurate because of demonstrated variations in total actual fish populations in identical sections from month to month. Also, the relative abundance of various species in the actual population of identical sections varied from month to month. The probable cause of the variation is the relative instability (with reference to position in the stream) of the more important components of the fish population, as demonstrated by the marking experiments. The repeated seinings at monthly intervals may have influenced the movements of the fish. The effect, if any, of repeated seining is not known.

An average stream depth of 14 inches or more was the only habitat characteristic that could be correlated definitely with a greater than average population of trout and other fish. Evaluation of other habitat factors affecting population density in trout streams must await more extensive research.

Conclusions concerning the proportions of the various age groups of trout in stream populations will not be offered until more collections from these and other Michigan streams are available.

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# THE CHEMISTRY OF IMPOUNDED WATERS AS A FACTOR IN GAME FISH PRODUCTION[1]

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## Abstract

Since 1931, the writer has been engaged in making a survey of small lakes and ponds for the New York Conservation Department Biological Survey. During this time, he has observed and studied a large number of new and old artificial lakes. These studies have included, among other important factors in fish production, an analysis of those chemical conditions that directly affect fish life. Studies were made on Minerva Lake over a period of several years after the construction of the lake.

From the many lakes studied, pertinent examples are chosen which indicate that:

In small newly impounded waters, chemical conditions tend, at first, to be unsuitable for game fish throughout the entire pond and therefore no stocking should be done.

As the impounded waters increase in age, an improvement in chemical conditions is noted, but this improvement usually involves only the surface layer of water. Stocking must hence be limited to species tolerant of warm surface temperatures. The colder bottom-waters rarely undergo sufficient chemical improvement to support cold-water species.

Each lake presents a new problem in itself but, in general, the rate and degree of recovery of newly impounded waters depend on the volume and temperature of the water passing through the pond, on the depth of the water, and on the type of vegetation established there.

The building of dams has been a common practice in this country since early colonial times. Dams have served as sources of power for grist and saw mills, as reservoirs for irrigation and canal systems or for the storage of water for domestic uses, and finally, as a source of electric power. More recently they have been proposed as a flood-control measure. Ordinarily the chemical condition of the water has not been important, for even in municipal water supplies almost any water may be made potable with modern methods of treatment.

Within recent years, because of the increased fishing intensity in all accessible fishing waters, impounded waters have become important for the food and game fish they produce. Attempts are being made not only to utilize the older artificial lakes and reservoirs to the limit of their capacity for fish production, but also numerous small lakes are constantly being constructed solely for recreational purposes and especially for the angling the fish population will provide. What sports-

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[1]The studies upon which this paper is based were conducted under the supervision of Dr. Emmeline Moore, Director of the New York State Conservation Department Biological Survey, and reported annually as Supplementals to the Annual Reports of the Conservation Department for the years 1932 to 1937. The chemical analyses were made by the various chemists associated with the pond unit of the Biological Survey.

man has not dreamed of his own lake abounding in large game fish? The damming of each stream of whatever size appears to offer great possibilities for the creation of artificial lakes that will supplement the fish supply of natural lakes. Unfortunately, desirable game fish are not tolerant of all waters and the success of new lakes as angling waters is dependent upon the suitability of the ecological conditions in the impounded waters for the survival, growth, and reproduction of fish. Temperature and chemical conditions of the water are of outstanding importance.

Since 1931 the writer has been engaged in making a survey of small lakes and ponds for the New York State Conservation Department Biological Survey. During this time he has had the opportunity to observe and study a large number of the smaller artificial lakes of the state.

Conditions in Minerva Lake (Essex County), first studied in 1932, aroused special interest in the chemistry of impounded waters insofar as it is related to fish life. The Minerva Lake dam was completed and the resultant lake basin was filled with water in the fall of 1931. At the time the first survey was made, the lake was less than one year old. It appears that the land flooded by the dam was carefully cleared and all precautions necessary to insure a clean lake were observed.

It was assumed by those interested that, since Jones Creek, the stream dammed, was a trout stream, the new lake would be a trout lake.

TABLE 1. CHEMICAL ANALYSES OF MINERVA LAKE

| Location of station | Date | Temperature in degrees F. | | Depth of sample in feet | Free $CO_2$ in p.p.m. | Dissolved oxygen | | pH |
|---|---|---|---|---|---|---|---|---|
| | | Air | Sample | | | p.p.m. | Percentage of saturation | |
| Middle of lake | Sept. 10, 1932 | 59 | 64 | B-12[1] | 20.0 | 0.0 | 0.0 | 6.8 |
| Middle of lake | Sept. 14, 1933 | ---- | ---- | B-15 | 12.0 | 0.1 | 1.1 | 6.0 |
| Middle of lake | Aug. 12, 1934 | 74 | 69 | B-14 | 23.1 | 0.0 | 0.0 | 6.6 |
| Middle of lake | Sept. 10, 1932 | 62 | 67 | S[2] | 17.0 | 2.5 | 27.8 | 6.8 |
| Middle of lake | Sept. 14, 1933 | ---- | ---- | S | 4.0 | 5.0 | 59.2 | 7.3 |
| Middle of lake | Aug. 12, 1934 | 74 | 74 | S | 0.0 | 10.3 | 119.1 | 9.1 |
| Southeast end of lake | Sept. 10, 1932 | 60 | 64 | B-14 | 102.0 | 0.0 | 0.0 | 6.0 |
| Southeast end of lake | Sept. 14, 1933 | ---- | ---- | B-16 | 97.0 | 0.0 | 0.0 | 6.0 |
| Southeast end of lake | Aug. 12, 1934 | 74 | 69 | B-15 | 23.0 | 0.0 | 0.0 | 6.7 |
| Southeast end of lake | Aug. 12, 1934 | ---- | 70 | 10 | 14.4 | 1.1 | 12.6 | 6.8 |
| Southeast end of lake | Sept. 10, 1932 | 59 | 67 | S | 17.0 | 0.0 | 0.0 | 6.8 |
| Nr. mouth of Jones Cr. | Sept. 14, 1933 | ---- | ---- | B-12 | 5.5 | 2.4 | 28.0 | 6.9 |
| Nr. mouth of Jones Cr. | Aug. 12, 1934 | 74 | 71 | B-10 | 10.1 | 0.1 | 0.6 | 7.1 |
| Northwest corner | Sept. 14, 1933 | ---- | ---- | B-10 | 12.5 | 2.3 | 26.9 | 6.8 |
| Northwest corner | Aug. 12, 1934 | 74 | 71 | B-10 | 20.4 | 0.0 | 0.0 | 6.7 |
| Northwest corner | Sept. 14, 1933 | ---- | ---- | S | 4.0 | 6.2 | 73.3 | 7.2 |

[1]Samples at depths preceded by B- were all taken about one foot off the bottom.

[2]Surface.

Accordingly, trout were stocked early in September, 1932, a few days before the first survey. Many of the stocked fish were found dead along the shores by the survey party. A chemical analysis (Table 1) of the water readily explained their death. Nowhere in the lake where temperatures were satisfactory for trout, was there sufficient oxygen for the respiration of fish. Even the surface water was low in dissolved-oxygen content (2.5 parts per million) and high in free carbon dioxide (17.0 parts per million). Some areas of the surface water lacked oxygen entirely. The cold bottom-waters were devoid of oxygen and contained 102.0 p.p.m. of free carbon dioxide. The only fish observed were a few horned dace and black-nosed dace near the inlet of Jones Creek.

The question arises as to whether adverse chemical conditions are characteristic of newly impounded waters, and, if so, whether the conditions later improved. To answer this question, surveys of Minerva Lake were made again in 1933 and 1934. The second year's analysis showed only slight improvement, and in 1934 conditions were still generally unfit for trout. The colder bottom-waters were still deficient in oxygen. The surface water, however, changed from a slightly acid condition accompanied by a scarcity of oxygen and a high concentration of carbon dioxide to an alkaline condition where the oxgyen concentration was high even to the point of super-saturation and where free carbon dioxide was either scarce or absent. Because of high surface temperatures these waters were not satisfactory for trout but were suitable for warm-water species.

A large proportion of Minerva Lake is shallow, and very dense weed-bed areas have become established. The abundance of vegetation accounts in part for the super-saturation of oxygen in certain areas, but, on the contrary, the dead vegetation causes oxygen depletion at greater depths.

The study of Minerva Lake also emphasizes the fact that when a trout stream is dammed with the intention of creating a trout pond, the size and depth of the pond to be created in relation to the volume of inflow must be considered. The volume of inflow from Jones Creek is so small in comparison with the size of the lake that conditions in the lake are only slightly affected by the stream, if at all.

Since the initial study on Minerva Lake, the writer has had the opportunity to study several other lakes soon after they were first filled, and in each lake general chemical conditions were very poor.

A comparison of Lotus and Laurel lakes (near Monticello, Sullivan County) provides some information concerning the speed of recovery of impounded waters. These two artificial lakes are situated along the same stream. They have approximately the same area and depth and are sufficiently near each other so that the bottoms and environs are similar. They differ mainly in age. In 1934, when the survey was made, Lotus Lake was 2 years old and Laurel Lake was 12 years old. The chemical conditions in Lotus Lake (Table 2), particularly the oxygen conditions, were poor. Surprisingly, however, in Laurel Lake

the oxygen values were also low, except at one station near the dam. In this area there was considerable swimming and therefore the water was thoroughly mixed from top to bottom. A comparison of the chemical analyses of these two lakes indicates that recovery has been extremely slow in Laurel Lake in spite of its shallowness. Undoubtedly it will be slow in Lotus Lake also.

**TABLE 2. CHEMICAL ANALYSES OF LAUREL AND LOTUS LAKES**
**(The significance of the symbols S and B is the same as in Table 1)**

| Name of lake and location of station | Date | Temperature in degrees F. Air | Temperature in degrees F. Sample | Depth of sample in feet | Free $CO_2$ in p.p.m. | Dissolved oxygen p.p.m. | Dissolved oxygen Percentage of saturation | pH |
|---|---|---|---|---|---|---|---|---|
| LAUREL LAKE— | | | | | | | | |
| Center | July 11, 1935 | 81 | 81 | S | 9.6 | 6.8 | 84.6 | 6.0 |
| | | | 69 | B-5 | 17.4 | 0.0 | 0.0 | 5.6 |
| Outlet end | July 11, 1935 | 81 | 65 | B-7 | 11.6 | 5.4 | 56.6 | 6.0 |
| LOTUS LAKE— | | | | | | | | |
| Center | July 12, 1935 | 80 | 76 | S | 5.8 | 6.1 | 72.0 | 6.2 |
| | | | 67 | B-7 | 30.0 | 0.0 | 0.0 | 5.6 |
| Outlet end | July 12, 1935 | 80 | 64 | B-8 | 43.4 | 0.0 | 0.0 | 5.8 |

The numerous small lakes in Palisades Interstate Park (Bear Mountain-Harriman Section) offered an excellent opportunity for further chemical studies on impounded waters. The exact dates when each lake was constructed are not known but the lakes may be grouped roughly as follows: those made before the area was purchased for park purposes in 1910, those made by the Park Commission from 1914 to 1926, and those constructed since 1933. The survey of this area was conducted in 1936 and for the purpose of this paper the lakes may be classified as those more than 25 years old, those 12 to 20 years old and those less than 3 years old at the time they were studied. Table 3 presents the chemical data for a few of the many lakes in Palisades Interstate Park.

A study of the lakes less than 3 years old substantiated findings in Minerva Lake. The concentration of oxygen in the bottom-waters was too low to support fish life and even the surface layer in many lakes was deficient in oxygen. The data for the older lakes make it evident that chemical conditions improve with time but the improvement apparently is limited to the surface layer. In general, conditions were suitable for fish life only in the better oxygenated water where tem-

**TABLE 3. CHEMICAL ANALYSES OF CERTAIN IMPOUNDED WATERS IN PALISADES INTERSTATE PARK (BEAR MOUNTAIN—HARRIMAN SECTION)**

**(The significance of the symbols S and B is the same as in Table 1)**

| Name of lake and location of station | Date | Temperature in degrees F. | | Depth of sample in feet | Free $CO_2$ in p.p.m. | Dissolved oxygen | | pH |
|---|---|---|---|---|---|---|---|---|
| | | Air | Sample | | | p.p.m. | Percentage of saturation | |
| **Lakes less than 3 years old** | | | | | | | | |
| BOCKEY SWAMP LAKE— | | | | | | | | |
| Outlet end | July 23, 1936 | 78 | 77 | S | 4.2 | 5.6 | 66.8 | 6.4 |
| Outlet end | July 23, 1936 | 78 | 65 | B-19 | 15.4 | 0.0 | 0.0 | 6.2 |
| West of center | July 23, 1936 | 78 | 65 | B-18 | 75.6 | 0.0 | 0.0 | 6.0 |
| Inlet end | July 23, 1936 | 78 | 74 | B-13 | 16.0 | 0.4 | 4.6 | 6.2 |
| PINE MEADOW LAKE— | | | | | | | | |
| Outlet end | Aug. 7, 1936 | 73 | 73 | S | 11.0 | 6.0 | 69.0 | 6.3 |
| Outlet end | Aug. 7, 1936 | 73 | 72 | 5 | ---- | 5.5 | 62.5 | --- |
| Outlet end | Aug. 7, 1936 | 73 | 71 | 10 | ---- | 4.4 | 49.6 | ---- |
| Outlet end | Aug. 7, 1936 | 73 | 61 | B-16 | 64.0 | 0.0 | 0.0 | 6.0 |
| Center | Aug. 7, 1936 | 72 | 59 | B-14 | 72.0 | 0.5 | 4.9 | 6.0 |
| Inlet end | Aug. 7, 1936 | 72 | 72 | B-9 | 15.6 | 3.6 | 40.9 | 6.2 |
| **Lakes 12 to 20 years old** | | | | | | | | |
| LOWER LAKE KANAWAUKE— | | | | | | | | |
| Outlet end | July 20, 1936 | 69 | 77 | S | 0.6 | 7.6 | 90.7 | 6.6 |
| Outlet end | July 20, 1936 | 69 | 68 | B-18 | 11.4 | 0.0 | 0.0 | 6.2 |
| Northeast end | July 20, 1936 | 69 | 78 | B-9 | 0.6 | 7.6 | 91.4 | 6.6 |
| UPPER LAKE KANAWAUKE— | | | | | | | | |
| Center | July 21, 1936 | 73 | 76 | S | 0.6 | 9.2 | 103.6 | 6.4 |
| Center | July 21, 1936 | 73 | 71 | 18 | 0.6 | 8.0 | 90.1 | 6.4 |
| Center | July 21, 1936 | 73 | 56 | B-36 | 8.8 | 1.8 | 17.0 | 6.0 |
| East end | July 21, 1936 | 73 | 75 | B-12 | 8.0 | 5.4 | 63.2 | 6.0 |
| **Lakes more than 25 years old** | | | | | | | | |
| BREAKNECK POND— | | | | | | | | |
| South end | Aug. 8, 1936 | 76 | 75 | S | 1.2 | 8.2 | 95.9 | 6.6 |
| South end | Aug. 8, 1936 | 76 | 72 | B-11 | 6.2 | 7.0 | 89.2 | 6.0 |
| Northeast of center | Aug. 8, 1936 | 76 | 75 | B-12 | 6.0 | 6.8 | 77.3 | 6.2 |
| BARNES LAKE— | | | | | | | | |
| Outlet end | July 28, 1936 | 81 | 78 | S | 1.2 | 8.2 | 99.0 | 7.2 |
| Outlet end | July 28, 1936 | 81 | 74 | B-9 | 10.0 | 1.8 | 20.9 | 6.4 |
| Inlet end | July 28, 1936 | 80 | 75 | B-5 | 29.6 | 8.0 | 93.7 | 6.8 |

peratures approximated the surface temperatures or in deeper waters subjected to mixing with the surface strata. The depth to which the improvement extends varies in individual lakes according to the size of the lake, the extent of exposure of the surface to winds, and possibly with reference to other factors.

The Kanawauke lakes present an interesting situation. The construction of a dam on the outlet of Little Long Pond created three more or

less separate lakes. The upper lake which includes the old, natural pond is the deepest. Although twice as deep as Lower Kanawauke, the waters of Upper Kanawauke have more favorable chemical conditions than those of the lower lake. Originally chemical conditions in Little Long Pond very probably were good. A comparison of the chemical data of these two lakes indicates that if a body of water is enlarged by damming the outlet, the chemical conditions of the natural lake or pond are retained in the larger body of water. Several observations in support of this conclusion have been made by the writer during the course of pond studies.

The importance of this type of investigation in relation to satisfactory results from the stocking of game species is obvious. Successful plantings cannot be expected in a body of water if only the uppermost strata are suitable for fish life. If chemical conditions in the deeper, cold water are unfavorable, stocking must be limited to warm-water species. The introduction of warm-water fishes may not be advisable particularly if a trout stream has been impounded to form the lake. Furthermore, the number of species of warm-water fish that may be introduced profitably very often is limited by the small size of the created pond. Many lakes, particularly those originally destined for trout ponds, are too small for large, warm-water game fishes such as bass, pike and pickerel. It usually happens that a small lake that was intended to be "the best little trout pond" or "the best little bass lake" is nothing more than another pan-fish pond and often a poor one, at that.

Each lake presents a new problem but, in general, the rate and degree of recovery of newly impounded waters depend on the volume and temperature of the water passing through the pond, on the nature of the land flooded, on the size and depth of the pond, and on the type of vegetation which is established.

The writer does not wish to infer that all small, artificial lakes are doomed to complete failure insofar as fish production is concerned. It should be emphasized, however, that a satisfactory habitat for fish is not merely a body of water. Careful planning is necessary to insure the success of the new lake. If it is planned to stock a lake with one particular species, the ecological requirements of that species should be known. The extent to which the lake meets these requirements should be determined. Of the many factors which determine the success of fish plantings in a new lake, chemical conditions are of extreme importance.

# THE RELATIONSHIP BETWEEN PLANKTON PRODUCTION AND FISH PRODUCTION IN PONDS[1]

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## ABSTRACT

**Experiments to determine the relationship between plankton production and fish production were conducted in a series of small, excavated ponds. The ponds were stocked with bluegill bream in May, and received four applications of inorganic fertilizers during the season. Water samples were taken from each pond every two weeks for quantitative and qualitative plankton determinations. The ponds were drained in November and the number and weight of fish from each were recorded. The data indicated that a direct relationship existed between plankton production and fish production.**

**A heavy production of plankton (76.1 p.p.m. of organic matter) formed a heavy scum of decaying organic matter on the surface of one pond on June 26. One-year-old fish died in this pond due to insufficient oxygen (the minimum concentration was 0.1 p.p.m.). Fry in the same pond survived.**

## INTRODUCTION

The relationship between food supply and fish production is recognized generally by fish-culturists. The relationship has been overlooked frequently, however, by farmers and sportsmen in the establishment of ponds for rearing fish. The usual practice has been to build a dam, to obtain as many fry or fingerlings as possible from state and federal hatcheries, probably to seine fish from a few creeks and add them to the original stock, and then to wait impatiently for the wonderful fishing to begin. Frequently, the results have been very disappointing, largely due to the lack of adequate food and to overstocking.

Plankton occupies a prominent place in the cycle of aquatic life. Authors of textbooks on botany as, for example, Wilson and Haber (1935) and Robbins and Rickett (1934), in attempting to set forth an economic justification for the study of algae state that these plants form the basic food supply for fish and other aquatic life. Many workers in the field of pond-fish culture have concerned themselves with the study of the natural plankton in lakes and ponds and of the fish production in the same waters and have attempted to make correlations between the two. Wiebe (1935) reviewed the work of many investigators who found that fertilizing ponds usually increased the fish production; few workers, however, have correlated increases in plankton production directly with increases in fish production.

Johnson (1933), who studied the lakes of the fertile-land region of

[1]Published with the approval of the Director.

Minnesota, stated: "Attempts to correlate plankton content of lakes with production of fish on the whole have proved to be not very successful. A scarcity of plankton is likely to be associated with a scarcity of fish, but the converse does not necessarily hold true."

Meehean (1935) wrote: "Samples taken in ponds, especially with reference to Oklahoma and Louisiana, have revealed that phytoplankton is of minor importance as to volume and numbers . . . ." and "In fertilized ponds the organic matter from zooplankton and phytoplankton is insignificant as compared with that from bacteria."

Surber and Olson (1936) studied the plankton and the chemical contents of the water of several ponds in Minnesota used for the production of fingerling bass. Some of the ponds were very productive and some gave very poor yields. A pond that produced less than 100 fingerling bass per acre was poor in net and centrifuge plankton as determined by the count method. The best pond, which produced from 6,000 to 9,000 fingerlings per acre, also had the highest plankton count.

In view of these different findings for controlled ponds and for natural lakes, it is well to consider further the possible role of plankton in the cycle of aquatic life. The addition of a balanced inorganic fertilizer to pond water containing carbon dioxide and exposed to sunlight usually will induce a rather heavy growth of phytoplankton in a short time. Apparently a few species of fish (not game fish) feed directly on phytoplankton. Goldfish and gizzard shad, for example, feed principally on phytoplankton and therefore may be used as forage fish. On the whole, however, plankton must be utilized by some other organisms eaten by fish, to be of any value in fish production.

Chironomid (midge) larvae and fresh-water shrimp, which feed on phytoplankton, are in turn eaten by bream, young crappies and bass, and thus form a bridge between phytoplankton and game or pan fish. An even more indirect method of utilization of phytoplankton is one in which the phytoplankton dies and is decomposed by bacteria. Some of the minerals and nitrogen of the phytoplankton are liberated but a large proportion of the carbohydrates and proteins is utilized by the metabolism of the bacteria. Some zooplanktonts such as cladocerans, copepods, and rotifers apparently feed on the bacteria and are themselves eaten by young fish.

There are, however, circumstances in which phytoplankton may play a minor part in the aquatic life cycle. Organic fertilizers, for example cottonseed meal or laying mash, may be eaten directly by fish or may be utilized by bacteria which are in turn eaten by zooplanktonts. Thus phytoplankton may be essentially omitted from the food cycle. In new ponds natural organic matter, in the form of dead leaves, twigs and bark, may serve as a source of carbohydrates for the bacteria on which zooplanktonts feed. The production of zooplankton and fish may be increased greatly by the addition of nitrogen and possibly other inorganic fertilizers.

## Experimental Methods and Results

The experiments were conducted in a series of fifteen small excavated ponds. Each had an area of approximately 334 square feet and a uniform depth of 3 feet. The ponds were fed by gravity through a pipe line that led from an unfertilized storage pond formed by a small impounded stream. Twelve ponds were fertilized with inorganic fertilizers and three were used as controls. Superphosphate, ammophos, sodium nitrate, ammonium sulfate, muriate of potash, calcium carbonate, gypsum, and basic slag were used separately or in various combinations, and were added on May 22, June 19, July 29, and September 3, 1936.

On May 22, each of ten ponds was stocked with 100 fingerling bluegill bream (*Helioperca macrochira*), that averaged 7.34 centimeters in length and 5.66 grams in weight. The total weight of fish placed in each pond was 1.25 pounds, equivalent to approximately 180 pounds per acre.

On the same date, each of five ponds was stocked with 200 newly hatched bluegill bream fry. The fry had an average weight of 0.034 grams and the total weight per pond was 0.25 ounces, equivalent to 2 pounds, 5 ounces per acre.

Plankton samples were taken from each pond every two weeks throughout the season, from May 22 to November 17, 1936, by means of a special sampler that took a vertical sample from the surface to the bottom of the pond. This sampler consisted of a galvanized metal cylinder 4 inches in diameter and 3 feet long. The lower end was open and fitted with a spring-operated door which could be closed by a trigger release. The upper end was closed except for a valve that could be closed with a plunger. The sampler, with the door and valve open, was inserted vertically until the lower end was near the bottom of the pond. The plunger and door were then released and the sampler with the retained vertical column of water was removed. Usually several samples from each pond were combined.

A liter sample of the water was reserved for a quantitative plankton determination according to the method described by Juday (1926). The sample was centrifuged by means of a Foerst electric centrifuge which concentrated the plankton into about 4 milliliters. The centrifuged sample was transferred to a porcelain crucible and dried in an electric oven at 60°C. for twenty-four hours after which the dried sample was weighed, incinerated in an electric furnace, and weighed again. The loss in weight due to incineration represented the amount of organic matter, which was recorded in parts per million.

A duplicate sample from each pond was centrifuged and examined with a wide-field binocular and a compound microscope. Generally the copepods, cladocerans, ostracods, and rotifers were the most important forms in the zooplankton. Since bream feed on zooplankton, counts of these organisms were made in order to determine whether a relation-

ship existed between the concentration of zooplankton and fish production. Although an abundance of organisms was usually correlated with high fish production, no definite relationship was established. This conclusion agrees with the findings of Johnson (1933) and others who have worked in natural lakes.

The most important orders of the phytoplankton represented were the Chlorococcales, Volvocales, Euglenales, and Zygnematales (Desmidaceae). Diatoms were frequently present as well as certain Dinophyceae. The phytoplanktonts were usually identified to genus but specific identifications were not attempted. No counts of phytoplankton were made as these organisms were frequently extremely small, and almost invariably constituted the bulk of the plankton reported as organic matter.

The ponds were drained on November 17 and 18, 1936, and the fish from each pond were counted and weighed. The one-year-old bream spawned in all ponds in which they were placed and from 10 to 87 per cent of them died in the various ponds. The greatest mortality was in the unfertilized control ponds. From 23 to 56 per cent of the fry (from the spring stocking) also died, and again the greatest mortality was in the control ponds. These percentages of mortality do not apply to Ponds 8 and 17. All of the one-year-old bream died in Pond 8 on June 26 and 27, because of insufficient oxygen. This mortality will be discussed later in the paper. Pond 17 was originally fertilized with ammonium sulfate and basic slag but this combination liberated free ammonia, raised the pH above 10.1, and killed all the fish within two days. The treatment was changed to ammophos, cal-

**TABLE 1. AMOUNT OF STOCKING AND YIELD OF BLUEGILL BREAM IN EXPERIMENTAL PONDS FERTILIZED WITH INORGANIC FERTILIZERS**

| Pond No. | —Placed in ponds May 22, 1936— | | | Recovered from ponds November 17 and 18, 1936 | | |
|---|---|---|---|---|---|---|
| | Class | Number per pond | Pounds per acre | Number of two-year-olds | Number of one-year-olds | Total weight, pounds per acre |
| 1 | Fingerling | 100 | 180.0 | 30 | 249 | 295 |
| 2 | Fry | 200 | 2.3 | — | 158 | 225 |
| 5[1] | Fingerling | 100 | 180.0 | 29 | 35 | 92 |
| 8 | Fingerling | 100 | 180.0 | — | 70 | 275 |
| 9 | Fry | 200 | 2.3 | — | 113 | 376 |
| 10[1] | Fry | 200 | 2.3 | — | 87 | 105 |
| 11[1] | Fingerling | 100 | 180.0 | 13 | 28 | 47 |
| 12 | Fingerling | 100 | 180.0 | 90 | 250 | 357 |
| 13 | Fingerling | 100 | 180.0 | 76 | 199 | 312 |
| 14 | Fingerling | 100 | 180.0 | 81 | 655 | 532 |
| 15 | Fingerling | 100 | 180.0 | 88 | 184 | 588 |
| 16 | Fry | 200 | 2.3 | | 154 | 358 |
| 17 | Fingerling | 46[2] | 180.0 | 33 | 771 | 362 |
| 19 | Fingerling | 100 | 180.0 | 77 | 463 | 431 |
| 20 | Fry | 200 | 2.3 | — | 146 | 229 |

[1]Control ponds not fertilized.

[2]All fingerling placed in this pond on May 22 died within two days and the pond was restocked with forty-six fingerlings on June 4.

**TABLE 2. THE AVERAGE PLANKTON PRODUCTION AND TOTAL FISH PRODUCTION IN PONDS FERTILIZED WITH VARIOUS INORGANIC FERTILIZERS AND STOCKED WITH BLUEGILL BREAM FINGERLINGS**

| Pond No. | Fertilizers | Average plankton production[1] | Total fish production in pounds and ounces per acre |
|---|---|---|---|
| 11 | None | 8.1 | 47- 4[2] |
| 5 | None | 5.1 | 92-11 |
| 1[3] | Superphosphate, sodium nitrate, calcium carbonate, muriate of potash | 30.3 | 295- 6 |
| 13 | Ammophos, basic slag | 18.3 | 312- 0 |
| 12 | Ammophos, calcium sulfate | 29.5 | 357- 0 |
| 17 | Ammonium sulfate, basic slag | 24.2 | 362-15 |
| 19 | Ammophos, basic slag, muriate of potash, potassium iodide | 23.0 | 431-13 |
| 14 | Ammophos | 31.1 | 532-14 |
| 15 | Superphosphate, basic slag, ammonium sulfate | 31.0 | 588- 0 |

[1]Organic matter in parts per million.

[2]Not considered representative; pond leaked badly and was often less than 1 foot deep.

[3]This pond received seepage water and frequently had an excessive amount of iron in the water.

**TABLE 3. THE AVERAGE PLANKTON PRODUCTION AND TOTAL FISH PRODUCTION IN PONDS FERTILIZED WITH VARIOUS INORGANIC FERTILIZERS AND STOCKED WITH BLUEGILL BREAM FRY**

| Pond No. | Fertilizers | Average plankton production[1] | Total fish production in pounds and ounces per acre |
|---|---|---|---|
| 10 | None | 4.4 | 105-11 |
| 2 | Superphosphate, sodium nitrate, calcium carbonate, muriate of potash | 8.0 | 225-14 |
| 20 | Ammophos, basic slag, muriate of potash, potassium iodide | 14.5 | 229-11 |
| 16 | Superphosphate, ammonium sulfate, basic slag | 18.8 | 358- 5 |
| 9 | Ammophos, basic slag, muriate of potash | 16.6 | 376-11 |

[1]Organic matter in parts per million.

cium carbonate and potassium chloride, and the pond was restocked with forty-six fingerling bream on June 4.

The number of fish stocked and recovered from each pond and the total weight from each pond are recorded in Table 1. The fish production is compared with average plankton production in Tables 2 and 3. A study of the data presented in these tables indicates an almost direct relationship between the average plankton production and fish production. Pond 15, stocked with fingerlings, had the highest fish production (588 pounds per acre) and it also had one of the highest average plankton productions (31.0 p.p.m. organic matter). Unfertilized control Ponds 5 and 10 produced 92 and 105 pounds of fish per acre respectively. Their average plankton productions for the season were only 5.1 and 4.4 p.p.m. organic matter respectively, as compared to

31.0 p.p.m. for Pond 15. It is interesting that Pond 5 was stocked with fingerlings at the rate of 180 pounds per acre while Pond 10 was stocked with fry at the rate of only 2 pounds, 5 ounces per acre; yet at the end of the season each was supporting approximately 100 pounds of fish. Pond 11, which supported only 47 pounds of fish per acre, was not a representative control because it leaked so badly that the water was frequently less than 1 foot deep. In every pond the fertilizer treatment, with the exception of ammonium sulfate plus basic slag, increased plankton production and more than doubled the yield of fish as compared to the yields from the representative controls. With one notable exception, comparable results were obtained from a preliminary experiment (September 9, 1935, to May 1, 1936). Pond 12, which was fertilized with ammophos and calcium sulfate, was one of the best ponds of the series on the basis of production of organic matter; yet it was a poor pond in terms of fish production. Observations of centrifuged plankton samples showed that in spite of the high production of phytoplankton, the concentration of zooplankton was extremely low and microcrustaceans were generally absent. The pH of the water in this pond, which varied from 6.4 to 4.3, was lower than in most of the other ponds. The paucity of zooplankton, apparently the result of the acidity of the water, probably explains the poor fish production.

Since the above data indicate a more or less direct relationship between plankton production and fish production, the question naturally arises as to the extent to which the plankton production may be increased with a corresponding increase in fish production. The results from Pond 8 partially answer this question. The phytoplankton, which bloomed rather vigorously in May, made a great flush of growth following the application of fertilizer on June 19. When samples were taken on June 26 it was found that the pond was covered with a heavy scum of decaying plankton and that the fingerling bream were dying. The dead bream were removed, and others died throughout the day and night. It was believed that depletion of the oxygen supply of the water as the result of decay of the heavy plankton scum caused the fish to die. Consequently, water samples were taken for oxygen determinations at 2 and 9 p. m. on June 26, and 4 and 9 a. m. on June 27 and analyzed according to the procedure given by the Association of Official Agricultural Chemists (1924). At the same hours, samples for comparison were taken from several other ponds in which the fish were not dying. The oxygen content of the water in Pond 8 was only 0.1 p.p.m. at 2 p. m., rose to 3.4 p.p.m. at 9 p. m., dropped to 0.8 p.p.m. at 4 a. m. the next day and again rose to 2.8 p.p.m. at 9 a. m. The increase in concentration of oxygen to 3.4 p.p.m. at 9 p. m. was apparently caused by the disturbance of the surface water during the removal of the dead fish. Fry that had hatched in this pond were not killed by the low oxygen concentration and by November were as large as the one-year-old bream in some of the ponds. The oxygen content

of the other ponds tested did not fall below 3 p.p.m. and was generally well above this figure.

It is evident, therefore, that heavy growths of plankton (as in Pond 8 that had 76.7 p.p.m. of organic matter on June 26), which on decaying may dangerously deplete the oxygen supply, are not desirable. A rather uniform growth of plankton throughout the warmer months giving an average of 15 to 30 p.p.m. organic matter is, however, conducive to a satisfactory yield of fish.


## Summary

1. A series of small excavated ponds received four applications of inorganic fertilizers between May and November. Qualitative and quantitative plankton determinations were made at two-week intervals during the experiment.

2. In every experimental pond the fertilizer treatment increased the production of plankton and more than doubled the production of bluegill bream as compared with unfertilized control ponds.

3. A direct relationship was found between the average production of plankton and the production of bream, in spite of the fact that no definite relation could be established between zooplankton alone and fish production.

4. A heavy scum of decaying organic matter on the surface of one pond caused by a heavy growth of plankton was responsible for the death of one-year-old bream. The dissolved-oxygen content of this pond was reduced to 0.1 p.p.m. Fry in this pond survived.


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# CERTAIN PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE LAKE, LOCH LEVEN, RAINBOW, AND BROOK TROUT

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Abstract

The changes in the weight of the organs and the body composition (proportions of moisture, protein, fat, and ash) of four species of trout have been followed during normal growth and after retardation of growth by underfeeding. The eyes tend to continue growth when the fish are underfed. Retarding of growth results in loss of fat and protein accompanied by an increase in the ash content. Underfeeding also results in the loss of fat in trout livers, and in some instances this loss of fat is accompanied by an increase in the iodine number values.

The fate of hatchery fish after planting is one of the chief problems facing the conservationists today. One of the most important of the many factors involved is the condition of the fish when they leave the hatchery. Few hatcheries are in a position to judge the condition of their fish except by visual appearance, which is not a good criterion if one bears in mind the complex structure of the animal body. A study of the physical and chemical characteristics of trout, features that determine the condition of the body, may be attacked from various angles. The items selected for this work were the weights of the organs and the chemical composition of the body.

It has been suggested that trout developed rapidly in the hatchery may prove to be weaklings under stream conditions. For this reason the effect of retardation of growth of the entire body upon specific parts of the body has been determined. There has been considerable interest during recent years in the development of fatty livers as a consequence of overfeeding and therefore the livers of trout of different ages and after a period of retardation in body growth have been studied.

Four species of trout were used in this study, the lake trout, *Cristivomer namaycush;* Loch Leven trout, *Salmo trutta;* rainbow trout, *Salmo gairdnerii irideus;* and brook trout, *Salvelinus f. fontinalis.* Fingerlings of each of the four species were placed in standard hatching troughs and fed a diet of fresh beef liver. Specimens were removed for dissection and analyses from each group on April 16, July

9, and October 1. These dates represented the beginning, middle, and end of a period of twenty-four weeks. Duplicate groups were set aside for each species on July 9. The growth of the latter groups was retarded by limiting the food allowance. Percentage mortality and percentage gain in weight of trout fed normally and trout fed the restricted quantity of food are compared in Table 1.

**TABLE 1. GROWTH, MORTALITY, AND FOOD CONVERSION OF FOUR SPECIES OF TROUT FED WITH FRESH BEEF LIVER[1]**

| Species of trout | Grams of dry liver per gram increase of live weight of trout | Per cent mortality per period of four weeks | Per cent gain in weight per period of four weeks |
|---|---|---|---|
| **Trout fed adequate amounts—April 16 to October 1** | | | |
| Lake | 1.2 | 0.4 | 60 |
| Loch Leven | 1.7 | 1.2 | 35 |
| Rainbow | 1.5 | 0.3 | 43 |
| Brook | 1.0 | 0.2 | 70 |
| **Trout retarded by restricted feeding—July 9 to October 1** | | | |
| Lake | 1.1 | 0.8 | 15 |
| Loch Leven | 1.2 | 9.3 | 15 |
| Rainbow | 1.0 | 0.3 | 16 |
| Brook | 0.8 | 0.4 | 20 |

| Item | Normal groups | Retarded groups |
|---|---|---|
| Range in number of trout used during experiments | 285 to 11,586 | 216 to 3,862 |
| Range in weight of trout carried per cubic foot of water (pounds) | 0.6 to 1.2 | 0.6 to 1.2 |
| Amount of food allowed daily, in per cent of the body weight of trout (average) | 8.0 | 2.0 |

[1]Average water temperature during period of experiments, 47° F.

The specimens taken from the four groups of normal fish at the beginning, middle, and end of the twenty-four week period were preserved in 10 per cent formalin until the organs were removed for study. At the end of the period the specimens from the retarded groups were treated likewise. One hundred sets of organs were used for obtaining the average weight at the beginning of the period; 25 at the middle; and, at the end, 100 of the lake and Loch Leven, 75 of the rainbow, and 50 of the brook trout were used. Of the retarded fish, 100 sets of organs of the lake, Loch Leven, and rainbow trout and 75 of the brook trout were employed for the determinations of average weight. Before weighing, the organs were placed in a funnel fitted with filter paper and all excess formalin allowed to drain. They were then transferred to clean dry filter paper and agitated with a needle. They were transferred to dry filter paper five successive times in order to remove the formalin as completely as possible. Weights were determined with an analytical balance. The relationships of the weight of the individual organs to the total weight of the trout are presented in Table 2.

TABLE 2. WEIGHT OF ORGANS OF TROUT IN TERMS OF PERCENTAGES OF TOTAL WEIGHT

| Species of trout | Date specimens were taken (1937) | Mean weight of trout in grams | Per cent of the body weight: Eye (one) | Heart | Liver | Gastro-intestinal tract (washed free of food) |
|---|---|---|---|---|---|---|
| Lake | April 16 | 0.2 | 1.70 | 0.18 | 1.05 | 5.80 |
| Lake | July 9 | 1.2 | 1.60 | 0.24 | 1.73 | 7.73 |
| Lake | October 1 | 4.4 | 1.28 | 0.30 | 1.48 | 6.43 |
| Lake[1] | October 1 | 1.9 | 2.12 | 0.24 | 1.59 | 7.14 |
| Loch Leven | April 16 | 0.2 | 1.88 | 0.25 | 1.05 | 6.63 |
| Loch Leven | July 9 | 0.7 | 1.51 | 0.21 | 1.29 | 7.07 |
| Loch Leven | October 1 | 1.9 | 1.45 | 0.22 | 1.24 | 5.33 |
| Loch Leven[1] | October 1 | 1.3 | 1.74 | 0.21 | 1.46 | 5.63 |
| Rainbow | April 16 | 0.6 | 1.68 | 0.30 | 0.92 | 5.70 |
| Rainbow | July 9 | 2.1 | 1.37 | 0.28 | 2.12 | 8.97 |
| Rainbow | October 1 | 6.2 | 1.01 | 0.31 | 1.46 | 6.57 |
| Rainbow[1] | October 1 | 3.4 | 1.60 | 0.29 | 1.56 | 6.64 |
| Brook | April 16 | 0.4 | 1.58 | 0.24 | 1.04 | 5.60 |
| Brook | July 9 | 3.4 | 0.86 | 0.22 | 2.21 | 8.59 |
| Brook | October 1 | 15.6 | 0.51 | 0.24 | 1.78 | 6.69 |
| Brook[1] | October 1 | 6.4 | 0.95 | 0.20 | 1.69 | 5.10 |

[1]Specimens from groups retarded from July 9 to October 1.

Both eyes were removed and weighed, but the weight of one eye only was compared with the total body weight. All excess fatty tissue was removed from the heart, liver, and gastro-intestinal tract. The digestive tract was excised at the anterior end of the oesophagus and at the anus. The tract was then slit open and all contents washed out.

The variable rates of growth in weight of different organs within the bodies of animals have long been recognized by the anatomist. When the animal is confronted with a shortage of or severe competition for food, certain parts of the body continue to grow, while others cease to grow. This behavior indicates that some anatomical parts secure nutrition and grow at the expense of other portions of the body.

The eyes of all species of trout studied continue to increase in weight when the growth of the entire body is retarded (Table 2). The per cent of the body weight constituted by the eyes is greater in the trout with retarded growth than in those with normal growth. This suggests the possibility of using eye weights as an additional "condition factor" to assist in evaluating the state of nutrition of trout in streams under natural conditions. Under conditions of normal growth the proportionate weight of the eye in relation to the body was much greater in the young trout than in the older fingerlings.

The results of the present study are in accord with those of other workers. White (1936) showed that each year-class of salmon parr has a characteristic eye diameter that may be used to some extent as an index of condition. Mottley (1936) in his work on the common characters used in the taxonomic study of salmonid fishes found that the percentage of the eye diameter in the standard length decreases as the fish increase in size.

The rate of growth of organs such as the heart and liver seems to fluctuate in different species at various periods of the year. In the lake trout only the heart seems to grow relatively faster than the rest of the body which growth rate may be a significant species character.

The bones of the normal and retarded trout were photographed by means of the X-ray, but no marked differences were observed in the bones of those fish that grew normally and those that were retarded.

It has been known for many years that the body composition of animals varies with age and size. The bodies of young animals contain proportionately more water than those of adults, and also when food becomes limited the water content increases. Such constituents as protein, fat, and minerals increase with growth in the young animal. If the growth is restricted by food shortage, then these constituents are used by the body to maintain life; the fat is depleted first, followed by the protein. There is some evidence that the bones of rats continue to grow when the growth of the rest of the body is retarded.

Table 3 shows the percentage composition of moisture, protein, fat, and ash in the bodies of the four species of trout fed normally, at the beginning, middle, and end of the twenty-four week period and the composition of those trout retarded in growth for the last half of the period.

**TABLE 3. PERCENTAGE COMPOSITION BY WEIGHT OF THE BODIES OF FOUR SPECIES OF TROUT**
**(Analyses by A. V. Tunison)**

| Species of trout | Date of sampling (1937) | Mean weight of trout in grams | Percentage of Moisture | Percentage of Protein | Percentage of Fat | Percentage of Ash |
|---|---|---|---|---|---|---|
| Lake | April 16 | 0.3 | 89.8 | 7.7 | 0.5 | 0.7 |
| Lake | July 9 | 1.2 | 81.6 | 13.2 | 1.5 | 1.2 |
| Lake | October 1 | 5.0 | 80.6 | 13.5 | 2.5 | 1.4 |
| Lake[1] | October 1 | 2.2 | 83.1 | 12.5 | 1.1 | 1.6 |
| Loch Leven | April 16 | 0.3 | 88.2 | 8.5 | 0.7 | 0.8 |
| Loch Leven | July 9 | 0.6 | 82.7 | 12.5 | 0.8 | 1.4 |
| Loch Leven | October 1 | 2.1 | 82.9 | 12.5 | 1.1 | 1.5 |
| Loch Leven[1] | October 1 | 1.5 | 82.0 | 13.3 | 1.0 | 1.8 |
| Rainbow | April 16 | 0.6 | 84.8 | 11.0 | 1.6 | 1.1 |
| Rainbow | July 9 | 2.2 | 78.2 | 13.5 | 4.0 | 1.5 |
| Rainbow | October 1 | 6.8 | 78.2 | 13.2 | 4.9 | 1.5 |
| Rainbow[1] | October 1 | 3.8 | 81.0 | 12.6 | 2.4 | 1.8 |
| Brook | April 16 | 0.4 | 87.2 | 9.2 | 0.8 | 1.0 |
| Brook | July 9 | 3.3 | 78.8 | 12.4 | 4.2 | 1.2 |
| Brook | October 1 | 15.0 | 75.4 | 14.2 | 6.6 | 1.4 |
| Brook[1] | October 1 | 7.4 | 78.6 | 14.0 | 3.8 | 1.6 |

[1]Specimens from groups retarded from July 9 to October 1.

The analyses were made in the usual manner[1] and anhydrous ethyl ether was used for the ether extract. Due to the fact that ether removes some of the ash, samples from the original material were em-

[1]Official and Tentative Methods of Analyses of the Association of Official Agricultural Chemists, Washington, D. C.

ployed for the ash determinations instead of the residue from the ether extract. Since the body increases in weight during preservation in formalin some error is introduced and calculations are not directly applicable to fresh fish. However, a simple correction converts the data to a dry weight basis and, thus, overcomes this error.

The samples employed for analyses of moisture, protein, fat and ash content consisted of seventy-five fish from each group removed at the beginning and middle of the period and twenty-five at the end, with the exception of the brook trout, of which only ten fish were used because of their size. Twenty-five fish from each of the retarded groups were employed. The samples were preserved in a 10 per cent formalin solution until the analyses were made.

There were no large specific differences in the results of the analyses. Since the samples were taken when the fish in the groups were of different sizes, the data can be correlated more directly with the age of the fish rather than with the size, although size of trout seems to be more important. All species of trout develop in the same way as other animals; the moisture content decreases and the protein, fat, and ash content increase during growth. Retardation of growth results in a loss of fat and protein content and an increase in the ash content.

Hewitt (1936) noted the occurrence of fatty livers in trout and associated this condition with high mortality in some instances. In the present investigation livers were removed from groups of the four species of trout at the beginning, middle and end of the twenty-four week period. These fish were analagous to those that were used for the organ-weight determinations and the body analyses. The livers were dried in vacuo and the fat determined by extraction with anhydrous ethyl ether. The results of the analyses are presented in Table 4. The data taken on successive dates show that in general the fat content of the liver increases with growth of fish. Retardation by underfeeding results in a decrease in liver fat. The brook trout attained the greatest growth during the twenty-four week period and had the highest fat content in the liver. Since no unusual mortality occurred it can be stated that the high fat content of the brook trout livers was not detrimental to the general health of the fish.

An increase in the liver fat of the lake and rainbow trout with a subsequent drop due to underfeeding, is accompanied by a decrease in the iodine number.[2] Underfeeding results in higher values of the iodine number. This does not hold for the Loch Leven trout (Table 3) but this species did not suffer great retardation due to the underfeeding and this may account for the values obtained for the iodine number. No explanation can be offered for variation in the iodine number of the brook trout.

This study was concerned with the changes that occur in the bodies of hatchery trout during periods of normal and retarded growth. It

[2]The iodine number is the weight in milligrams of iodine that will combine with one gram of fat. It is merely a means for characterizing fat.

**TABLE 4. CHANGES WITH AGE IN THE FAT CONTENT OF THE LIVERS OF VARIOUS SPECIES OF TROUT AND THE EFFECT OF RETARDATION**

| Species of trout | Date of sampling (1937) | Number of livers used | Average dry weight of livers in grams | Per cent fat in dry liver | Iodine number (Hanus) |
|---|---|---|---|---|---|
| Lake | April 16 | 785 | 0.000785 | 4.2 | 90 |
| Lake | July 9 | 490 | 0.005080 | 5.0 | 77 |
| Lake | October 1 | 134 | 0.016300 | 6.5 | 71 |
| Lake[1] | October 1 | 344 | 0.008200 | 4.6 | 81 |
| Loch Leven | April 16 | 1,173 | 0.000740 | 5.2 | 80 |
| Loch Leven | July 9 | 971 | 0.002070 | 3.6 | 58 |
| Loch Leven | October 1 | 337 | 0.008040 | 6.2 | 87 |
| Loch Leven[1] | October 1 | 531 | 0.004800 | 4.6 | 67 |
| Rainbow | April 16 | 727 | 0.001600 | 5.6 | 67 |
| Rainbow | July 9 | 265 | 0.009300 | 5.6 | 60 |
| Rainbow | October 1 | 87 | 0.027000 | 6.4 | 52 |
| Rainbow[1] | October 1 | 181 | 0.015000 | 4.7 | 68 |
| Brook | April 16 | 832 | 0.001300 | 5.0 | 86 |
| Brook | July 9 | 233 | 0.011000 | 9.1 | 70 |
| Brook | October 1 | 50 | 0.068000 | 11.9 | 76 |
| Brook[1] | October 1 | 85 | 0.032000 | 4.2 | 64 |

[1]Specimens from groups retarded from July 9 to October 1.

is preliminary to the study that must eventually be made of our stream fish. Such investigations will require experimental streams which are expensive not only as to initial costs but in regard to operating expenses as well. When experimental streams are available to the scientist, hatchery fish of known length, weight, body composition, and physical characteristics can be used in stocking, and the subsequent changes in these factors studied at various periods. The data presented in this paper may serve as a basis for such future studies and offer problems which must be overcome before a complete picture of the situation can be obtained. In order to predict the fate of hatchery fish after planting, more exacting studies must be made of the natural food and environmental conditions of the stream as well as of the condition of the fish at the time of planting. The manufacturer cannot often change the composition of his raw products, but by varying the amounts of each used he can usually produce a commodity of desired composition. If the legal trout in the fisherman's creel is the finished product, the hatchery-reared trout may be considered the raw material.

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# A COMPARISON OF FOUR EASTERN SMALLMOUTH BASS STREAMS[1]

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## Abstract

Four smallmouth bass streams in the Potomac River watershed are compared. In the largest stream, the Shenandoah River near Berryville, Virginia, the fingerling bass (*Micropterus dolomieu*) grew to an average length of 4.25 inches during 1936, whereas in the South Branch of the Potomac near Romney, West Virginia, fingerlings attained a length of 2.75 inches by the end of the summer. In the Shenandoah River and probably also in its North Fork, bass grow rapidly and attain the legal size of 10 inches in three years, but in the South Branch of the Potomac and in the Cacapon River from four to six years or more are required for the fish to grow to legal size. The muddy condition of the Shenandoah and North Fork for long periods during the summer affects the success of natural propagation. These streams also have extensive riffle areas over limestone ledges where bass find shelter while feeding. In the South Branch of the Potomac and in the Cacapon River the riffles are short and little shelter is available.

Bottom samples collected in riffles of the four streams failed to show any marked difference in the abundance of organisms. Samples from pools of the South Branch, however, contained approximately twice as much potential bass food as pools of the Shenandoah River. A number of faunal differences in these streams are pointed out. In the clear streams such insect larvae as *Eriocera*, *Atherix*, and *Chauliodes* and the mayfly nymphs of *Isonychia* and *Iron* are more abundant than in the muddy streams where Sphaeriidae, Oligochaeta, larvae of *Elophila* and parnid beetles, and nymphs of *Potamanthus* are more abundant.

The extent of natural propagation in the four rivers was studied quantitatively. The smaller, clearer streams have the most extensive natural propagation. In the small, clear streams, there are many bass but their slow growth indicates serious food competition. In the South Branch of the Potomac the extent of natural propagation is probably about five times greater per mile length of stream than in the Shenandoah River which produces the fastest growing fish of any of the four streams studied.

A seasonal study of the food of fry and fingerling smallmouth bass was made from monthly collections during 1936 in the Shenandoah River and South Branch of the Potomac. The chief items of food were mayfly nymphs of the genus *Baetis* and chironomid larvae. Entomostraca (chiefly *Cyclops*) played a minor role in the food of bass in both streams. In the Shenandoah River, 9.9 per cent of the fry which averaged 10.0 millimeters in length on May 13, 1936, had consumed fish.

The livers of the South Branch fingerling bass contained large numbers of trematode cysts but relatively few were found in the livers of the Shenandoah River bass. There was no evidence that the presence of trematode cysts affected the growth rate, since infested and uninfested fish were very nearly the same size.

Minnow censuses were made on the four rivers. The data given in part, although to a certain extent inaccurate, at least afford some idea of the relative abundance of the more important forage fishes.

These studies indicate that much information of very practical value can be gained by actual field studies of bass streams. In some of these streams it is evident that the stocking of bass is a mistake.

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[1]Published with the permission of the U. S. Commissioner of Fisheries.

## Introduction

Within a radius of 70 miles from the experimental station at Leetown, West Virginia, are four well-known smallmouth bass streams all of which are in the Potomac River watershed. The largest of these streams, the Shenandoah River (main branch), affords excellent fishing when it is clear, but during July, August, and September it is usually too muddy for fishing. Anglers catch many bass in this stream that weigh over 2 pounds and a relatively large number of bass that weigh from 4 to 5 pounds, but fish over 5 pounds in weight are rare. In the South Branch of the Potomac and in the Cacapon River, the bass taken run small in size, and only a few large individuals weighing 4 pounds or more are taken each year. The proportion of undersized fish is relatively large.

Growth studies show that nearly all bass in the Shenandoah River reach the legal size of 10 inches in three years whereas in the South Branch of the Potomac and in the Cacapon River from four to six years are required. The Shenandoah River drains a relatively rich agricultural section and during heavy showers the plowed clay fields contribute much silt or mud which causes the almost continuous roily condition of the river during the summer. In contrast to the relatively clean bottom and shore line of the Cacapon River and the South Branch of the Potomac, the Shenandoah and its North Fork have deposits of silt and mud over the rocky ledges, banks, piles of shore debris, and tree trunks beyond the water's edge. A greater abundance of willows overhang the banks of the last-named streams. The South Branch of the Potomac and the Cacapon River flow through rather narrow mountain valleys. The South Branch valley contains considerable expanses of flat bottom lands used for agriculture and grazing. The Cacapon valley, on the other hand, is narrow throughout and supports very little agriculture.

The long periods of muddy water, particularly in the lower Shenandoah, affect the success of natural propagation of the bass. The North Fork of this river does not appear to be silted as much as the main river. Even before our bass investigations began, it was observed that bass fry and young of the year were fairly abundant along the shores of the Shenandoah in June and early July, but by October they were much less numerous than in the South Branch of the Potomac. For some unknown reason (which we are attempting to determine) the roily condition of the Shenandoah River causes a sharp and rapid reduction of the population of fry and small fingerlings. Those that survive enjoy less food competition and, therefore, grow more rapidly. Thus the muddy condition of the Shenandoah probably has an indirect beneficial effect on the growth rate of bass in that river. Data collected during 1936 and 1937 indicate that the growth rate of bass is unaffected by long periods of existence in muddy water.

In late September and October, 1935, the Shenandoah River became

so clear that one could see the bottom, even in the deep pools. It was observed during this period that in spite of the previous successful angling there were in reality very few bass present in this river. This condition was in marked contrast to the South Branch of the Potomac where both adult and young bass were seen in relatively large numbers, whenever the water was clear and its temperature above about 60° F. In the Shenandoah River, bass of legal size always occurred in groups, sometimes as large as eleven or more individuals. On one occasion a school of nine bass swam out from beneath a large square boulder, and at another time when a bass was hooked, a school of ten individuals, all large fish, rushed to the boat and attempted to take the lure already set in the jaw of the hooked fish. The occurrence of schools of bass accounts for the variable success of bait fishermen who seek deep holes in the river near rocky riffles where such schools may be expected to occur.

The point which the writer wishes to emphasize is that the Shenandoah River, a large stream, has relatively few bass, but a large proportion of them were of good size. On the other hand, the South Branch and the Cacapon River, relatively small streams, have dense populations of bass in relation to the available food supply but the majority of the fish are relatively small. Actual field studies will determine whether or not our bass streams should be stocked. It is surmised that a large part of the equipment now being used for the propagation of bass in this section of the country might be devoted more profitably to the culture of forage fishes.

The growth rates of fingerling smallmouth bass in the Shenandoah River and the South Branch of the Potomac were compared during 1936 when river conditions permitted good monthly collections through the growing season. In the Shenandoah River, fingerling bass attained an average length of 4.25 inches by September 22, whereas in the South Branch they attained an average length of only 2.75 inches during the same length of time. Not only bass but stonerollers (*Hypentelium nigricans*) and common suckers (*Catostomus commersonnii*) grew more rapidly in the Shenandoah than in the South Branch.

In 1937, when the Cacapon and the North Fork of the Shenandoah River were added to the number of streams under observation, high water prevented really adequate collections in all of the rivers. The data collected showed that fingerling bass in the Shenandoah River were nearly 2.5 inches long by July 30; South Branch bass were about 2.7 inches long by September 13; Cacapon River fingerlings about 2.8 inches in length by September 1; and bass from the North Fork of Shenandoah slightly more than 3.0 inches long by September 16.

### Bottom Fauna

The effect of the numerous limestone springs in the Shenandoah valley upon the waters which drain it is shown by chemical analyses

of the water (Table 1). The chemical nature of these waters together with their silt loads affects the kind of organisms found in them as evidenced by the predominating molluscs. In the South Branch and the Cacapon River, many snails of the species *Nitocris carinatus* Bruguiere occur, but comparatively few Sphaeriidae are found although they are very abundant in the riffle areas of the Shenandoah and its North Fork. The large *Lampsilis ovata cohongoronta* Ortmann is found in the South Branch and in the Cacapon River, but it is either absent or very scarce in the Shenandoah River. *Elliptio complanatus* (Dillwyn), a rather large and thick-shelled mollusc, is found in fairly large numbers in all four rivers but is most abundant in the Shenandoah system. Crayfish are most abundant in the South Branch and the Cacapon River.

**TABLE 1. A COMPARISON OF CHEMICAL DATA COLLECTED ON FOUR BASS STREAMS**

| Name of river | Methyl orange alkalinity p.p.m. | Phenol-pthalein alkalinity p.p.m. | Free carbon dioxide p.p.m. | pH | Dissolved oxygen p.p.m. | Tempera-ture, de-grees F. | Date, 1938 |
|---|---|---|---|---|---|---|---|
| South Branch of Potomac River | 30.6 | 0.00 | 6.0 | 7.1 | 10.2 | 59.0 | April 27 |
| Cacapon River | 44.5 | 0.00 | 3.7 | 8.1 | 9.3 | 62.0 | April 28 |
| Shenandoah River | 112.5 | Trace | 0.0 | 8.3 | 10.0 | 70.0 | May 1 |
| North Fork of Shenandoah River | 121.9 | Trace | 0.0 | 8.3 | 9.7 | 69.0 | April 30 |

During 1936, quantitative studies were made of the bottom organisms in riffles of the South Branch of the Potomac and of the Shenandoah River. From this study it was observed that in the South Branch (Figure 1), beginning in May, 1936, the average number of organisms per square foot over a seven-month period was 93.6. The average wet weight with molluscs included was 2.48 grams, and with molluscs excluded, 0.93 grams per square foot. During the same period the averages in the Shenandoah River were 118.8 organisms with wet weights of 3.38 grams (molluscs included) and 1.42 grams (molluscs excluded) per square foot. High water prevented the collection of samples during April, August, and October.

Samples were collected from riffles during the 1937 seasons in the Cacapon River and North Fork of the Shenandoah. In the Cacapon, the average number of bottom organisms per square foot was 147.5 during a five-month period from June to October. The average wet weights of bottom animals were 5.21 grams per square foot with molluscs included and 0.85 gram per square foot with molluscs excluded. Collections in the North Fork of the Shenandoah River were

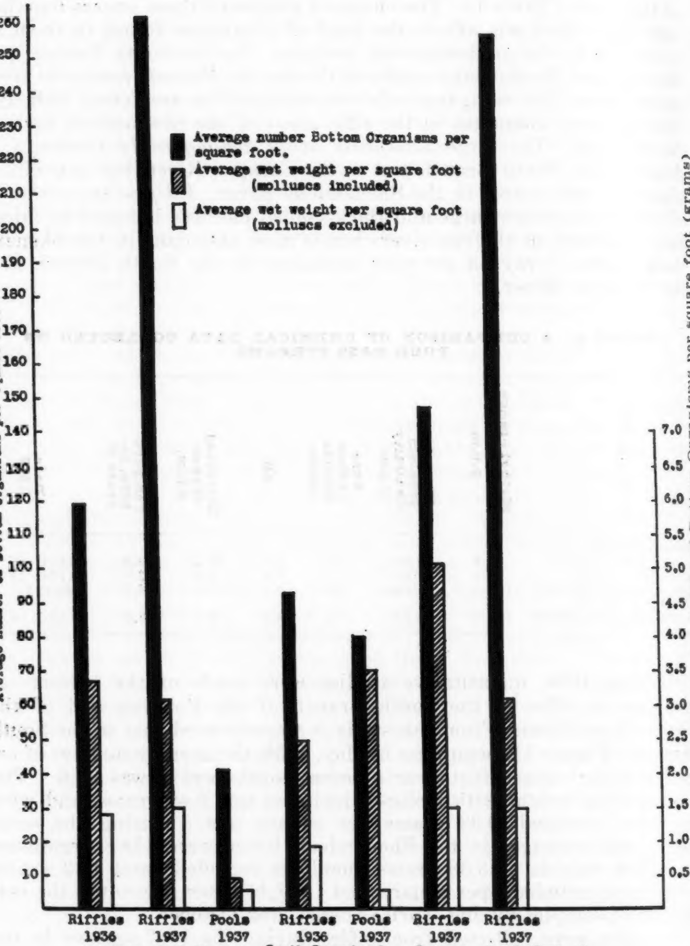


Fig. 1. Average number of bottom organisms and wet weight (inclusive and exclusive of molluscs) in four bass streams.

only made during the months of June, July, and September since high water prevented collecting at other seasons. The average number of organisms per square foot was 257.0. Here the average wet

weights were 3.24 grams per square foot with molluscs included and 1.50 grams with molluscs excluded.

During 1936, the following forms were more abundant in the South Branch of the Potomac than in the Shenandoah River: crayfish, certain snails, mayfly nymphs (*Isonychia* and *Iron*), cranefly larvae (*Eriocera*), snipe fly larvae (*Atherix*), and fish-fly larvae (*Chauliodes*). The following forms were the more important in the Shenandoah River: caddis larvae (*Hydropsyche*), bristle worms (Oligochaeta), mayfly nymphs (*Potamanthus*), hellgrammites (*Corydalus*), aquatic moth larvae (*Elophila*), parnid beetles, and molluscs (Sphaeriidae and *Elliptio*). Mayfly nymphs of the genus *Iron* were not found in the Shenandoah.

The faunal characteristics of the Cacapon River resemble those of the South Branch. *Iron* and *Atherix* were abundant, and in addition an unidentified caddis larva with tiny cases (probably *Brachycentrus*) was found in large numbers attached to the larger stones and boulders in fast water.

During 1937, a comparison was made of the bottom fauna of the Shenandoah River pools in the test section near Berryville, Virginia, with that of the pools of the South Branch in the test section near Romney, West Virginia. In both streams the number and quantity of organisms per square foot in the pools were much less than in the riffles. The South Branch contained about twice as much fish food in the pools as was found in the pools of the Shenandoah River. Oligochaetes and nymphs of the mayfly *Hexagenia* were more abundant in the Shenandoah samples, but *Baetis, Ephemera,* and *Potamanthus* nymphs, *Eriocera* and chironomid larvae were more abundant in pools of the South Branch of the Potomac.

The section under observation in the North Fork of the Shenandoah River is smaller than the section that we are studying in the main river, but the two sections are alike in the possession of extensive riffle areas in which the river flows briskly or falls abruptly over limestone ledges and fragments of limestone and other sedimentary rocks. Both areas are rich in fish food, and the bass live and feed where there is good shelter. In contrast, the South Branch of the Potomac and the Cacapon River have, for the most part, short, gravel and rubble riffles which are relatively inaccessible to the bass. Bass do not feed as much in these areas as in the long pools that separate the short stretches of shallow, swift water.

During floods the grinding action on the bottom of the riffles of the South Branch and the Cacapon River undoubtedly destroys much of the bottom fauna. Actually, the total bottom fauna in the Shenandoah River is quantitatively greater than that in the other streams.

## Extent of Natural Propagation of Bass

There is great variation in the abundance of materials suitable for the construction of bass nests in the four streams. The Cacapon and

South Branch abound in suitable areas for nesting. Suitable bottom materials and protected areas are relatively scarce, however, along the banks of the Shenandoah and its North Fork below Strasburg, Virginia.

Ideal conditions were found in 1938 for the observations of the extent of natural propagation of smallmouth bass in these rivers. When the spawning season began all streams were clear and low following a long period of abnormally dry weather. The data (Table 2) collected by George E. Klak and the writer illustrate differences in the extent of natural propagation in these streams.

During 1936 and 1937, no evidence was found of a second or later spawning. In 1938, however, convincing evidence of a second spawning was found in the South Branch and in the Cacapon River. The second spawning occurred a month later than the first, and like it, occurred in both streams simultaneously. The second spawning followed a long period of cool weather and two sudden rises in these rivers caused by heavy showers, which resulted in muddy water. During this interval between the two spawning periods the fry from the first spawning were almost all destroyed. No such catastrophe occurred in these two streams during 1937 or in the South Branch during 1936. The first rise in these rivers took place immediately after the fry had risen from their nests. It therefore appears that high and muddy water in these streams at this time may destroy practically all of the fry. The data on the second spawning appear in the lower half of Table 2. The Shenandoah River was too muddy for detection of further nesting on June 6, but no great difficulty was encountered in the collection of fry from the first spawning. Judging from the variation in the lengths of the fry, a later spawning must have occurred in this river also.

The South Branch of the Potomac River was clear and satisfactory for observations on the extent of natural propagation during 1936 and 1937 when 142 and 205 nests, respectively, were counted in the same section in which 155 nests were observed in 1938. Conditions in the other streams were not satisfactory for observations during 1936 and 1937.

The rather extensive natural propagation (Table 2) is probably adequate for the maintenance of the stocks, except perhaps in the main stream of the Shenandoah. There is grave danger in stocking a stream beyond its capacity to provide sufficient food for the planted fish to grow to legal size. A large number of bass just under the legal size occurs in the South Branch of the Potomac and in the Cacapon where bass spawn annually and produce thousands of fry, many of which are probably consumed by the larger bass. The stocking of these streams with forage fish such as the blunt-nosed minnow, attractive minnow, and mad tom (if this species can be reared artificially) should be undertaken on a large scale. As an alternative the size limit on bass should be temporarily reduced or removed in order to decrease

TABLE 2. DATA ON THE NUMBER AND DIMENSIONS OF BASS NESTS IN FOUR BASS STREAMS, 1938

| Item | Cacapon River | Shenandoah River (main stream) | North Fork of Shenandoah River | South Branch of Potomac River |
|---|---|---|---|---|
| **First spawning** | | | | |
| Date of survey | April 28 | April 29 | April 30 | May 2 |
| Water temperatures, degrees F. | 67.0 | 71.0 | 68.0 | 69.0 |
| No. of acres in test section | 86.4 | 159.1 | 109.4 | 83.3 |
| Average width of river (feet) | 150.0 | 350.0 | 190.0 | 250.0 |
| Length of sect. surveyed (mi.) | 4.8 | 3.8 | 4.8 | 2.8 |
| Number of nests | [1]105 | [2]41 | [1]56 | [2]155 |
| Number nests per mile | 44.2 | 10.9 | 23.5 | 56.4 |
| Number nests per acre | 2.4 | 0.3 | 1.0 | 1.9 |
| Number containing eggs | 68 [3](64.8) | 26 [3](63.4) | 8 [3](14.3) | 14 [3]( 9.0) |
| Number containing fry | 2 ( 1.8) | 5 (12.2) | 23 (41.1) | 95 (61.3) |
| Number with fry risen | 0 ( 0.0) | 0 ( 0.0) | 21 (37.5) | 40 (25.8) |
| Number without eggs or fry | 35 (33.3) | 10 (24.4) | 4 ( 7.1) | 6 ( 3.9) |
| Aver. depth of nests (inches) | 25.6 | 22.4 | 27.0 | 27.5 |
| Max. depth of nests (inches) | 43.5 | 38.0 | 37.8 | 60.5 |
| Min. depth of nests (inches) | 6.3 | 15.0 | 13.3 | 6.5 |
| Aver. distance from shore (ft.) | 6.8 | 9.3 | 8.7 | 10.0 |
| **Second spawning** | | | | |
| Date of survey | June 10 | None | None | June 14 |
| Water temperatures, degrees F. | 75.0 | ---------- | ---------- | 77.0 |
| Number of nests | [1]63 | ---------- | ---------- | [1]34 |
| Per cent of first spawning | 60.0 | ---------- | ---------- | 43.9 |
| Number containing eggs | 8 [3](12.7) | ---------- | ---------- | 0 [3]( 0.0) |
| Number containing fry | 7 (11.1) | ---------- | ---------- | 5 (14.7) |
| Number with fry risen | 40 (63.5) | ---------- | ---------- | 28 (82.4) |
| Number without eggs or fry | 8 (12.7) | ---------- | ---------- | 1 ( 2.9) |
| Aver. depth of nests (inches) | 24.6 | ---------- | ---------- | 18.5 |
| Max. depth of nests (inches) | 48.0 | ---------- | ---------- | 32.0 |
| Min. depth of nests (inches) | 6.0 | ---------- | ---------- | 8.0 |
| Aver. distance from shore (ft.) | 8.7 | ---------- | ---------- | 7.5 |
| Total nests per mile including first and second spawnings | 70.7 | ---------- | ---------- | 81.0 |
| Total estimated number fry produced per mile | 120,253 | 18,587 (?) | 40,084 (?) | 137,855 |
| Estimated number fry per acre | 6,611 | 438 (?) | 1,740 (?) | 4,551 |

[1]Right side of stream.

[2]Both sides of stream.

[3]Percentage of total number of nests is given in parenthesis

the obviously too dense populations in the South Branch and in the Cacapon River. Experimentation in large areas of a stream should precede large-scale attempts at population control.

The quantitative study on the extent of natural propagation in bass streams resulted in a fairly good estimation of the magnitude of the bass population of spawning size. (We believe the size at maturity to be at least 8 inches because we have seen no bass under this size attending a nest.) If, for example, 223 bass nests are counted in a 2.75-mile length of river, we may estimate that there are probably 446 bass of a length of 8 inches or larger in that section of river. Random samples of wild fish show that the sexes are nearly equally abundant. The number of bass per mile of river can be used to derive other useful information such as the number of pounds of food which should be produced in that section to enable bass to grow to a certain size.

## Studies of the Food of Fry and Fingerling Smallmouth Bass

During the winter and spring of 1937, the stomach contents of 1,076 fingerling bass were examined by Dr. James S. Gutsell and the writer. The samples were collected at monthly intervals between May 13 and October 27, 1937, in the test sections of the South Branch of the Potomac and in the Shenandoah River. Collections were adequate for a study of the changes in the food of growing fingerlings from the time they rose from the nests until about the end of the growing season. Approximately 10 per cent of the Shenandoah River fry averaging 10.0 millimeters in length on May 13 had consumed fish. Many of the fry had not completely absorbed their yolk material. The chief items of food of the fry, however, were mayfly nymphs of the genus *Baetis* and chironomid larvae. Entomostraca (chiefly *Cyclops*) played a minor role in the food of fry in both the Shenandoah and in the South Branch of the Potomac River. In the fry (average length 12.2 millimeters) collected on May 22, 1936, from the South Branch of the Potomac, fish constituted a much less important food item than in the bass fry of the Shenandoah River. Otherwise the principal food items were the same in the two rivers. The mayfly nymphs of *Baetis, Heptagenia,* and *Isonychia* and chironomid larvae were prominent items of food throughout the period of observation. As the bass grew to a larger size, fish became more important in the diet, except in the South Branch of the Potomac where there was a scarcity of forage minnows. Black toad tadpoles were consumed by 10 per cent of Shenandoah River bass (averaging 41.6 millimeters in length) on June 17.

During removal of the stomachs from these fish for food studies, it was noticed that the livers of the South Branch bass fingerlings contained an abundance of trematode cysts. These cysts were more prevalent in the livers of bass from the South Branch than in those of the Shenandoah bass. In the July collection of South Branch fingerlings, 72.8 per cent had infected livers. At the same time only 11.1 per cent

of the Shenandoah River bass had trematode cysts. In the late August and in the October collections 57.8 and 80.2 per cent, respectively, of the South Branch fingerlings were infested with the cysts, while in mid-August and late September 12.8 and 10.5 per cent of the livers of the Shenandoah bass were infested. Livers of the South Branch bass contained, on the average, many more cysts than those of the Shenandoah bass. There is no evidence that the presence of cysts in these fish affected their growth rate, for the average size of infested and uninfested fish was very nearly the same.

## Abundance of Forage Fish

During the last two years several fish censuses have been attempted with the primary objective of determining the abundance of forage minnows. It is not practical to attempt an enumeration of forage fish populations in large streams by seining. During the spring of 1938, after some practical experience in the actual counting and weighing of lots of black-head and blunt-nosed minnows, George E. Klak and the writer undertook a careful minnow census on our four streams while they were clear. The results are given in Table 3.

Our general impression was that there are more minnows per unit area of stream in the Shenandoah River where bass reach the legal size of 10 inches in three years than in the other streams. However, our spring census failed to show that the Shenandoah River had more minnows per unit area than, for example, the South Branch of the Potomac River. However, if we calculate the number of forage fish per bass seen or per bass nest counted during the surveys, the greater food supply for bass in the Shenandoah River and its North Fork is very evident.

The most important forage fish for fingerling bass in these rivers are the attractive and rosy-faced minnows, *Notropis amoenus* and *N. rubellus*, and the blunt-nosed minnow *Hyborhynchus notatus*. Other important forage fish are: *Schilbeodes insignis, Lepomis auritus, Notropis hudsonius, Hypentelium nigricans, Catostomus commersonnii,* and *Leucosomus corporalis*. *N. amoenus* and *N. rubellus* are very active, and the adults are usually found where there is considerable current—where the swift water tapers off into pools below riffles. These minnows are at some distance from the banks where the bass are able to capture them. The blunt-nosed minnow, on the other hand, remains near the shore and in the weed beds of the water willow, *Dianthera americana,* where they are probably more difficult to capture. The mad tom, *Schilbeodes insignis,* is probably also important, particularly in the Shenandoah River where it is a favorite bait for bass. Our census of forage fish unfortunately did not include an estimate of the abundance of this species which is nocturnal in its habits.

There is also a distinct difference in the relative abundance of other species of fish, including rock bass (*Ambloplites rupestris*), sunfish (*Lepomis auritus* and *Apomotis cyanellus*), fallfish (*Leucosomus cor-*

**TABLE 3. RESULTS OF MINNOW CENSUS OF FOUR BASS RIVERS, 1938**

| Item | South Branch of Potomac | Cacapon River | Shenandoah River | North Fork of Shenandoah River |
|---|---|---|---|---|
| Date of survey | April 26 | April 28 | April 29 | April 30 |
| Length of test section (miles) | 2.8 | 4.8 | 3.8 | 4.8 |
| Average width of test section (ft.) | 250.0 | 150.0 | 350.0 | 190.0 |
| Area of test section (acres) | 83.3 | 86.4 | 159.1 | 104.4 |
| Total number schools of minnows observed | 62 | 78 | 282 | 160 |
| Number of schools per mile | 22.5 | 16.4 | 75.2 | 33.7 |
| Number of schools per acre | 0.7 | 0.9 | 1.8 | 1.5 |
| Estimated number of individuals observed (all schools) | 25,198 | 7,810 | 24,451 | 6,284 |
| Estimated number of individuals per mile | 9,162 | 1,644 | 6,520 | 1,322 |
| Estimated number of individuals per acre (production) | 302.4 | 90.4 | 153.7 | 60.1 |
| **Blunt-nosed minnows** *(Hyborhynchus notatus)* | | | | |
| Total number of schools observed | 24 | 18 | 65 | 72 |
| Average number of schools per mile | 8.7 | 3.8 | 17.3 | 15.2 |
| Average number of schools per acre | 0.3 | 0.2 | 0.4 | 0.7 |
| Estimated number of individuals observed | 15,978 | 5,360 | 12,659 | 3,128 |
| Estimated number of individuals per mile | 5,810 | 1,128 | 3,375 | 658 |
| Estimated number of individuals per acre | 191.8 | 62.0 | 79.6 | 29.9 |
| Number of schools of young (length 1 inch) per mile | 0.0 | 0.4 | 0.5 | 0.4 |
| Number of schools of intermediates (length 1 to 2 in.) per mi. | 5 | 2.5 | 10.1 | 3.4 |
| Number of schools of adults (length 2 to 5 inches) per mile | 3.6 | 0.8 | 6.7 | 11.9 |
| Average number of individuals per school (all sizes) | 665.8 | 297.8 | 143.8 | 43.4 |
| Average number of individuals in schools of young | 0.0 | 20.0 | 50.0 | 25.0 |
| Average number of individuals in schools of intermediates | 640.7 | 380.0 | 232.5 | 38.6 |
| Average number of individuals in schools of adults | 700.8 | 190.0 | 149.0 | 45.3 |
| **Attractive minnows** *(Notropis amoenus)* and/or **Rosy-faced minnow** *(N. rubellus)* | | | | |
| Total number of schools observed | 38 | 60 | 217 | 88 |
| Average number of schools per mile | 13.8 | 12.6 | 57.9 | 18.5 |
| Average number of schools per acre | 0.4 | 0.7 | 1.4 | 0.8 |
| Estimated number of individuals observed | 9,220 | 2,450 | 11,792 | 3,156 |
| Estimated number of individuals per mile | 3,352 | 515 | 3,144 | 664 |
| Estimated number of individuals per acre | 110.6 | 28.4 | 74.1 | 30.2 |
| Number of schools of young (length 1 inch) per mile | 7.3 | 11.4 | 35.7 | 11.4 |
| Number of schools of intermediates (length 1 to 2 in.) per mi. | 4.4 | 0.8 | 15.2 | 3.4 |
| Number of schools of adults (length 2 to 5 inches) per mile | 2.2 | 0.4 | 6.9 | 3.8 |
| Average number of individuals per school (all sizes) | 242.6 | 40.8 | 65.2 | 35.9 |
| Average number of individuals in schools of young | 70.5 | 38.7 | 36.5 | 18.2 |
| Average number of individuals in schools of intermediates | 622.5 | 70.0 | 89.1 | 53.8 |
| Average number of individuals in schools of adults | 56.6 | 40.0 | 70.0 | 72.8 |

*poralis*), stone rollers (*Hypentelium nigricans*), and carp (*Cyprinus carpio*) in the streams studied. Rock bass and sunfish are very abundant in the Cacapon River, but rock bass are very scarce in the South Branch of the Potomac River, and relatively few occur in the Shenandoah River. Sunfish are numerous in all of these streams, but are least abundant in the Shenandoah. Fallfish and stone rollers are more abundant in the clearer streams, the South Branch of the Potomac, the Cacapon River, and perhaps the North Fork. Carp are most abundant in the Shenandoah.

Of the four streams the Shenandoah River appears to be the best balanced stream with respect to the ratio of the number of forage fish to the number of bass. This balance probably is a result of the curtailment of natural propagation of bass by a lack of good spawning areas and by the severe environmental conditions which reduce the survival rate. Consequently, there are relatively few fish to compete for the available food.

The advice and supervision of Dr. H. S. Davis, In Charge of Aquicultural Investigations, U. S. Bureau of Fisheries, are gratefully acknowledged. Dr. Henry van der Schalie and Mr. Calvin Goodrich of the Museum of Zoology, University of Michigan, identified the molluscs referred to in this paper.

## Discussion

Acting Chairman Foster: What are the approximate rises in the water level of those streams?

Mr. Surber: There are some tremendous rises in water elevation. In the South Branch of the Potomac in 1936 there was a rise of 18 feet during the flood, and spawning occurred some time later. The flood occurred, I believe, on March 17, and we made our first observations on spawning on May 1 and 2. The flood couldn't have had a great deal of effect on the abundance of bass, because we found almost as many nests that year as we did later.

In the Shenandoah River the rise is even greater. The high-water mark is up near the tree tops—probably 25 or 30 feet from the ground.

Acting Chairman Foster: That has been my experience in Missouri, and I asked the question for the benefit of Mr. Barker, who is very anxious to establish the smallmouth in New Mexico.

Mr. H. B. Woodward: How much silt is carried during the periods of rises?

Mr. Surber: We made no quantitative study of the amount of silt carried, but the amount is tremendous. The South Branch of the Potomac and the Cacapon clear up very quickly, however.

Here is a point I omitted—a very interesting observation made this spring. We found that the results of the first spawning in the Cacapon River and the South Branch of the Potomac were entirely wiped out by floods. We were counting nests when the fry were in them and almost ready to rise, and we are reasonably certain that the majority of those nests produced fry that were later scattered. Then a sudden rise in the river (in fact two rises) occurred and when we came back to collect the fry, which we have never had trouble in doing before, in the South Branch of the Potomac we were able to collect only fifteen fry. We didn't see the fry. They were gone! Approximately 300,000 fry were absolutely wiped out. But the second spawning produced another crop of fry which compensated, to a certain extent, the destruction of the fry which resulted from the first spawning.

In the Cacapon River the same thing happened. In some years there is a flood with very muddy water that may entirely wipe out the hatch of fry.

Mr. E. L. Wickliff: Are crawfish important in the food of smallmouth bass?

Mr. Surber: We haven't made an intensive study, but I feel certain that crawfish constitute a very important item of the bass food.

Acting Chairman Foster: Just to clarify your statement, when you refer to the second spawning do you refer to a later spawning of fish which did not spawn earlier in the season?

Mr. Surber: That's right. I think a cool spell interrupted the regular season, because we found no evidence of later spawning during two preceding seasons. This is contrary, I believe, to observations on spawning in artificial ponds, because I know that at our station we have had later spawnings of bass, perhaps on successive rises in temperature, but in these rivers the simultaneity of the spawning has been a marked feature.

Mr. A. D. Aldrich: I would like to ask Mr. Surber if the spotted bass coexists in any of the streams with the smallmouth, or are the streams outside of the range of spotted bass?

Mr. Surber: Our streams are out of their range. The spotted bass is found in southern West Virginia, southwestern Virginia, but not in our section.

Mr. H. H. MacKay: I would like to ask Mr. Surber if he made any observations concerning the percentage of mortality of bass, say 9 and 10 inches long, as compared with bass 12 inches in length. Did you observe the difference in the mortality of eggs laid by 9- and 10-inch bass?

Mr. Surber: We counted the number of fungused eggs in nests but only in rare instances were any numbers of dead eggs found.

Mr. MacKay: One of our investigators has observed that the eggs of the older and larger bass, approximately 12 inches long, are much stronger, and certainly the mortality is much less than that of eggs laid by smaller bass, approximately 9 and 10 inches. Can you verify that observation?

Mr. Surber: No, we have been surprised that we did not find bass of smaller size spawning in these rivers. The bass have been, I think, without exception, over 8½ inches in length, probably over 9 inches. We haven't attempted to study that phase of it yet.

Mr. Wickliff: Is the second spawning due to the same bass or a different crop of bass?

Mr. Surber: We, of course, would be unable to tell that. Female fish have been actually known to spawn a second time in artificial ponds.

Mr. Wickliff: Couldn't they be caught and tagged the first time?

Mr. Surber: We rarely catch the female and rarely see the female at the nest. The male, of course, is almost always present. It would be rather difficult, under natural conditions, to catch and tag the females.

Mr. T. C. Fearnow: Mr. Surber's findings make it evident that these streams are receiving naturally a tremendous number of fry every year. I would like to ask him whether or not he has discovered a critical size at which the heavy loss occurs in these fry.

Mr. Surber: There is little doubt but that the heaviest loss occurs within a week after the fry rise from their nests. They disappear even under the best

conditions. In 1936 the South Branch of the Potomac was very clear. The bottom was visible in 15 feet of water, I believe, and the fry, or the bulk of the fry, disappeared within one week after they rose and scattered. We have collected sunfish and rock bass, associates of the bass in these streams, but so far we haven't been able to get any incriminating evidence against either the sunfish or the rock bass, although we find the rock bass eats more fish than do the sunfish. We find very few fish taken as food by the red-bellied sunfish, *Lepomis auritus*, which is the common sunfish in these streams.

DR. H. S. DAVIS: We, as you know, find a comparable loss of the fry in hatchery ponds, and this ordinarily has been ascribed to cannibals. That explanation has never completely satisfied me, and this year I have been trying to make a few observations on the losses of fry at Hackettstown and Leetown. We found that at both places the fry are heavily parasitized even at the time they rise from the nest. Two of the parasites found on fry are undescribed. Fry of the largemouth bass seem to have an entirely different set of parasites than the fry of the smallmouth bass in the same hatchery.

The smallmouth parasites are largely protozoan. In addition, in the largemouth at Hackettstown we found a mixture of sporidia on the gills. Fry brought in from the municipal reservoir (fry hatched from wild fish in the natural water) were fairly loaded with *Ichthyophthirius*. I don't see how the fish could possibly survive the number of parasites on them. That parasite has not been found on the fish hatched either at Hackettstown or at Leetown. I am firmly convinced that a large part of the early loss among the fry is due to parasites.

MR. SURBER: I would like to add that Dr. Davis examined a series of fry from several of our ponds at Leetown. There we found for the first time dead fry scattered over the bottom, no doubt due to parasites.

# THE DETERMINATION OF THE FOOD GRADE OF STREAMS

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Abstract

The volume and number of organisms per unit area of bottom is now widely used in determining the relative richness of streams. The food grade determined by the volume of organisms in square-foot samples is an important factor in the calculations used to determine the number of fish to plant per mile of stream. In spite of the fact that thousands of dollars may be wasted by making an incorrect estimate no one seems to have investigated some of the fundamental problems involved in the determinations. Some of these problems are: (1) What is an *adequate* sample; how many square-foot samples are needed to afford a reliable estimate? (2) What is the seasonal fluctuation in food organisms; can samples taken at different seasons be used as reliable estimates? (3) Do all the organisms taken in the samples become available to the same extent to the particular species of fish a stream is to support.

Preliminary findings of the Laboratory have shown that there is considerable variation in the food grade as determined by a number of workers in one spot at one time and that floods and high water may completely alter the picture.

## Introduction

Fishery investigators have been attempting to obtain a measure of the relative productiveness of streams by ascertaining the amount of potential food present at a given time in the hope that it might serve as an index of the number of fish that the stream will support. This measure, called the food grade, is now a routine determination and is one of the important factors used for drawing up stocking policies in the several states where the survey method is in vogue.

The actual method of determining the food grade varies. In New York State the investigator turns over a few stones and makes a cursory examination of the quality and quantity of food organisms. The U. S. Bureau of Fisheries and some states use the more elaborate "square-foot" method[1] described by Davis (1938). The success of the New York method undoubtedly depends on the experience of the investigator while the latter can be used by any reliable field worker. However, it should be pointed out that the efficiency of both methods has not been thoroughly tested in terms of fish production.

Only a few attempts have been made to carry the determination of the productiveness of streams beyond the preliminary stages reported by Leger (1910), Embody (1927), and Needham (1928). Workers in this field have devised a standard technique for collect-

[1]This method might be more appropriately called the "quadrat" method in conformity with accepted ecological terminology.

ing the potential food from a unit area of bottom but the significance of the data has not been clearly demonstrated. Nevertheless, the data are being used regularly to calculate the number of fish to be planted in streams. No one seems to have made any attempt to determine whether square-foot samples afford a true picture of the richness of a stream. Surber (1937) attempted to find out whether a certain food grade actually represents a definite capacity of the stream to produce a certain amount of fish. The chief difficulty in interpreting any of the reported data arises from the failure of the authors to use a standard statistical treatment.

There appear to be two important problems which need to be solved before values, such as the food grade, can be used efficiently in a stocking program: (1) Can the richness of a stream be measured accurately? (2) Can this measured richness be correlated with the measured production of trout?

As a step toward finding an answer to the first question the advanced students of limnology at Cornell University[2] undertook the problem of determining the food grade of Cascadilla Creek in October, 1937. From the data obtained by the class it has been possible to make a statement of some of the fundamental issues underlying this question, and it is the purpose of this paper to discuss some of them. The main problems fall into two categories: (1) problems centering around the use of a standard quadrat, such as the square foot (these are "yardstick" problems); and (2) sampling problems, concerned chiefly with the question of the reliability of the samples for the determination of the quality, quantity and distribution of the natural populations of food organisms.

## Yardstick Problems

There are two main problems in this category and both of them hinge on the fact that a quadrat does not take into consideration the natural arrangement of habitats in a stream. In riffles, for instance, it is a common practice to speak of the rubble as a homogeneous habitat. Actually the rubble is not homogeneous. The surfaces of the individual stones are the habitats for most of the organisms found there and careful study demonstrated that the stones are not arranged uniformly in the riffles.

The first difficulty is that the area outlined by the frame of the sampler is only two-dimensional. The sampler probably is quite satisfactory for homogeneous bottoms where a continuous single-layered surface is exposed, such as bedrock, hardpan, clay, silt, muck, marl or sand. In these habitats there is usually very little stratification

[2]The authors are indebted to the following students for data supplied: D. Benson, S. M. Brown, R. L. Crowell, D. R. Embody, L. C. Pettit, A. M. Phillips, W. F. Royce, J. T. Tanner, A. H. Underhill, H. E. Warfel, R. L. Weaver. Since the project included 140 individual samples involving the identification, usually to genus, of about 15,000 organisms it could not have been accomplished without their aid.

of the organisms. On the other hand where rooted vegetation exists or where the bottom is composed of detritus, gravel, rubble or boulders there is a tendency toward heterogeneity with a great increase in the number of potential habitats for organisms at different levels.

The use of a quadrat to compare these two main bottom types is much like the use of a standard city block to contrast the density of the human population in blocks of single dwellings with the population in blocks of apartment houses. The value obtained is a statement of the total number of organisms present at a given time but it does not disclose how densely the various habitats within the area are populated. For instance, a rubble bottom may contain more organisms than a similar area of sand but at the same time the rubble has more habitats per unit area than the sand owing to the greater habitable surface area within the quadrat. A total count, therefore, gives no indication of the density in each habitat. A census of the habitats would also be necessary, but this census presents many practical difficulties. As in the comparison of single dwellings and apartment houses the number of individuals per unit area of floor space might give a better index of density, so the number of organisms per unit of substratum exposed to the water might be a better way of measuring the richness of a stream.

The quantity of organisms present beneath a square foot of surface of stream bottom may, therefore, be simply a measure of the density of population with reference to a unit area, but it is not necessarily a measure of the richness of that area. The richness can be determined only by measuring the density of population in each of the natural habitats. This consideration seems to be of fundamental importance in measuring the food grade of a stream.

The second difficulty in the use of the quadrat method concerns the error involved in determining the actual boundaries of the area. In this respect the quadrat is not at all like a city block, which is a clear-cut unit. The houses do not project into the streets in the manner in which the stones of a rubble bottom extend beyond the frame of the sampler. The stones may measure more than an inch or two in diameter and the boundary may cut across many natural units. If the stones are brought into the area to remove the organisms clinging to them, a considerable error may be introduced. It is difficult, therefore, to decide how much to include or exclude in a square foot sample. In the ordinary sampling method errors as high as 30 per cent or more may be expected. This large range of error throws some doubt on the validity of the quadrat method, particularly for rubble bottoms.

A third but minor difficulty relative to the square foot as a unit is the complication introduced by the use of mixed systems of meaurement. Volumes, weights and final results for scientific purposes

**TABLE 1. NUMBER OF AQUATIC INSECTS OF SEVERAL ORDERS OBTAINED FROM 1,000 SQUARE-CENTIMETER SAMPLES FROM CASCADILLA CREEK FROM OCTOBER 11 TO 15, 1937, BY EIGHT DIFFERENT WORKERS**

| Worker | Trichoptera | Diptera | Plecoptera | Ephemeroptera | Neuroptera | Coleoptera | Total[1] |
|---|---|---|---|---|---|---|---|
| A | 155 | 41 | 5 | 38 | 0 | 5 | 244 |
| A | 91 | 74 | 0 | 26 | 1 | 2 | 194 |
| A | 179 | 26 | 1 | 34 | 0 | 0 | 240 |
| A | 47 | 7 | 1 | 19 | 0 | 0 | 74 |
| A | 98 | 4 | 3 | 22 | 0 | 5 | 132 |
| | | | | | | | **177** |
| B | 31 | 6 | 3 | 12 | 0 | 2 | 54 |
| B | 26 | 2 | 10 | 3 | 0 | 4 | 45 |
| B | 112 | 46 | 2 | 14 | 0 | 12 | 186 |
| | | | | | | | **95** |
| C | 54 | 9 | 6 | 19 | 0 | 22 | 110 |
| C | 48 | 10 | 7 | 2 | 0 | 17 | 84 |
| C | 79 | 14 | 10 | 2 | 0 | 9 | 114 |
| C | 255 | 4 | 3 | 1 | 1 | 6 | 270 |
| C | 235 | 21 | 5 | 1 | 0 | 24 | 286 |
| C | 144 | 33 | 0 | 1 | 0 | 40 | 218 |
| | | | | | | | **180** |
| D | 11 | 1 | 9 | 0 | 0 | 11 | 32 |
| D | 24 | 3 | 6 | 4 | 0 | 10 | 47 |
| D | 149 | 0 | 3 | 18 | 0 | 3 | 173 |
| D | 207 | 35 | 6 | 12 | 0 | 1 | 261 |
| D | 334 | 44 | 4 | 29 | 0 | 7 | 418 |
| | | | | | | | **186** |
| E | 185 | 11 | 8 | 59 | 0 | 5 | 268 |
| E | 79 | 82 | 3 | 30 | 0 | 2 | 196 |
| E | 98 | 61 | 2 | 11 | 0 | 0 | 172 |
| | | | | | | | **179** |
| F | 25 | 17 | 1 | 2 | 0 | 11 | 56 |
| F | 48 | 26 | 4 | 0 | 0 | 6 | 84 |
| F | 36 | 9 | 8 | 14 | 0 | 20 | 87 |
| | | | | | | | **76** |
| G | 78 | 43 | 3 | 24 | 1 | 3 | 152 |
| G | 115 | 57 | 0 | 35 | 0 | 2 | 209 |
| G | 286 | 22 | 1 | 21 | 3 | 4 | 337 |
| G | 159 | 27 | 2 | 30 | 1 | 6 | 225 |
| G | 67 | 18 | 3 | 31 | 1 | 2 | 122 |
| | | | | | | | **209** |
| H | 50 | 9 | 0 | 28 | 0 | 0 | 87 |
| H | 30 | 10 | 2 | 4 | 0 | 1 | 47 |
| H | 119 | 8 | 2 | 25 | 0 | 2 | 156 |
| H | 181 | 20 | 5 | 40 | 0 | 1 | 247 |
| H | 25 | 2 | 8 | 5 | 0 | 0 | 40 |
| | | | | | | | **115** |
| Mean | 110.29 | 22.9 | 3.89 | 17.6 | 0.23 | 7.0 | 161.9 |
| Variance | 6,586.0 | 458.0 | 8.44 | 205.0 | — | 72.7 | 8,863.0 |
| Standard deviation | 81.2 | 21.4 | 2.9 | 14.3 | — | 8.5 | 94.1 |

[1]The mean for the determinations of each worker is printed in boldface type.

are usually recorded in the metric system. It would certainly simplify procedure if everyone adopted the metric system for this work. The Laboratory of Limnology and Fisheries at Cornell University is using 1,000 square centimeters as the standard quadrat which is only 7.5 per cent larger than the square foot (929 square centimeters).

## Sampling Problems

The foregoing problems are related to variations and errors in the unit used for measuring the abundance of organisms in streams.

This second set of problems is concerned chiefly with the question: Can a sample provide an accurate measure of the whole natural population? This phase of the study is concerned with the variations in the organisms themselves, their distribution within their habitats and their annual and seasonal fluctuations in abundance. Can these variations be measured without collecting the whole population? It all depends on how the organisms are distributed in space. If distribution is random then a series of unselected samples may be taken from which the distribution of the whole population can be calculated easily on a statistical basis. Unfortunately no one has attempted to find out how the organisms on the various types of stream bottom are distributed. Ricker (1937), has given a valuable lead in this direction as applied to plankton sampling. His data will undoubtedly have a profound effect on the conclusions being drawn from current fresh-water plankton investigations.

The majority of investigators using the bottom sample method of estimating the food grade of streams—for example Behney (1937)—have tacitly assumed that the organisms are distributed at random and, therefore, random sampling and average values are sufficient for determinations of food grade.

The project undertaken by the limnology class was designed chiefly to find out how the organisms in a stream are distributed. The numbers of organisms in the major groups of aquatic insects counted in thirty-seven samples from rubble bottom are shown in Table 1. According to Ricker's interpretation of similar data it may be concluded that the distribution of aquatic insects, at least, are not distributed at random but are definitely bunched. The distribution of the samples with respect to volume exhibits a decided skewness; the values are given in Table 2.

**TABLE 2. FREQUENCY DISTRIBUTION OF THE VOLUME DETERMINATIONS OF 1,000 SQUARE-CENTIMETER SAMPLES FROM CASCADILLA CREEK, OCTOBER, 1937**

| Volume in cubic centimeters | Number of samples |
|---|---|
| 0.0 to 0.4 | 2 |
| 0.5 to 0.9 | 8 |
| 1.0 to 1.4 | 9 |
| 1.5 to 1.9 | 7 |
| 2.0 to 2.4 | 3 |
| 2.5 to 2.9 | 2 |
| 3.0 to 3.4 | 3 |
| 3.5 to 3.9 | 2 |
| 4.0 to 4.4 | 1 |

As a result of these findings we are forced to the position suggested by Snedecor (1937) who stated that "if large samples of enumeration data do not follow either binomial or Poisson distributions, there is no alternative but the disagreeable one of treating them as normal. Conclusions, if any, should be tentative."

Let us assume for the time being, as other workers have done, that the distributions are normal and that a small number of samples can be used to determine the natural populations. Let us also assume that the master sample of thirty-seven affords the best picture of the true distribution. The mean number of aquatic insects (Table 1) is 161.9 and the standard error of this average is 15.9. This statement merely means that on the basis of random distribution and random sampling 95 per cent of all such samples will fall within the limits of 130 to 194. We have the values turned in by the eight field workers whose samples in Table 1 make up the master sample. Only four or 50 per cent of the means of their samples fall within the expected range instead of the 95 per cent.

Turn now to the determinations based on volume which are ordinarily used in arriving at the food grade. Here there are thirty-seven samples having a mean volume of 1.66 cubic centimeters. The standard error of this value is 0.18 cubic centimeter which means that 95 per cent of such samples, if the distribution and sampling are perfectly random, will fall between 1.3 and 2.0 cubic centimeters. Actually the values turned in by the eight workers were distributed as follows: 1.6, 0.7, 2.2, 1.6, 1.3, 1.4, 1.6, and 2.3 cubic centimeters. Only five, or approximately 60 per cent fall within the expected range.

We conclude from these data that the method does not give a very reliable picture of the natural populations of aquatic insects.

The samples given in Table 1 were taken during the second week of October, 1937. It had been planned originally to take additional samples during the third week to add to the master sample, but heavy rains occurred at the end of the second week and a period of high water ensued. Samples taken during the third week showed a marked decrease in the number and volume of the organisms (Table 3).

**TABLE 3. DECREASE IN THE NUMBER AND VOLUME OF AQUATIC INSECTS IN CASCADILLA CREEK BEFORE AND AFTER A PERIOD OF HIGH WATER, OCTOBER, 1937**

| | Number of samples | Mean number of organisms | Number of samples | Mean volume of organisms |
|---|---|---|---|---|
| Before high water | 35 | 161.9 | 37 | 1.66 |
| After high water | 37 | 63.9 | 30 | 0.52 |

This period of high water therefore had a profound effect on the food grade of the stream, as it is ordinarily determined. Before the high water, the food-grade determinations (based on the method of Embody, 1927) were distributed as follows: Grade 1, 12 samples; Grade 2, 15 samples; Grade 3, 10 samples. (Corrections have been

made for the difference between the size of our 1,000 square-centimeter quadrat and the standard square-foot quadrat.) The mean value of 1.66 cubic centimeters placed the stream in Grade 2. After the high water, the distribution of the samples was as follows: Grade 1, 2 samples; Grade 2, 2 samples; Grade 3, 26 samples. The important point here is that in the course of a few days the stream suddenly dropped from Grade 2 to Grade 3. This change was undoubtedly due to the scouring action of the water, which incidentally swept the rocks clean of an abundant growth of algae. In streams of this type at least, which are subject to sudden fluctuations in volume, the food-grade determinations are, therefore, not very reliable. It is difficult to judge just what effect this may have on the food-grade determinations made by surveys working only during the summer months.

Some fundamental research on the determination of the productivity of streams appears to be highly desirable, particularly from a practical standpoint. Large sums of money are expended in stocking streams. If the food grade or its significance are being estimated incorrectly by ordinary survey methods, inefficiency and an inevitable waste of funds will result. According to standard calculations, as outlined by Embody (1927), the factor for food grade produces a difference in the final results of twenty-seven 3-inch trout per foot of width per mile of stream. For every foot of width an additional twenty-seven fish are added, so that in a stream 10 feet wide an overestimate of one in the food grade would result in an addition of 270 to the planting per mile. An overestimate of the food grade would amount to an error of 23 per cent in a Grade 2 stream. The practical result is that a mistake of this type would entail a very serious error in the total number of fish to be planted in a watershed. Since the cost of 3-inch fish is over twenty dollars per thousand, overestimation might easily become an important item in the fish-culture budget. The worst feature of the situation is that without a comprehensive system of checking the results of stocking, incorrect stocking may continue for years without discovery. The money so wasted could finance a large number of research projects.

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# OBSERVATIONS ON THE RESPIRATION OF TROUT FINGERLINGS AND A NEW METHOD OF TRANSPORTING SPECKLED TROUT (*SALVELINUS FONTINALIS*)

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ABSTRACT

**In view of the necessity of securing a method for the most economical transportation of trout, conditions permitting the accommodation of considerable numbers of fingerlings in relatively small volumes of water, have been determined. A uniform distribution of the fish in the tank is obtained through their vertical separation into groups by the use of perforated metallic shelves; this arrangement prevents the huddling of the fish at the bottom of the tank, and their consequent exhaustion through the continuous struggle they exhibit when this crowding occurs. It insures, at the same time, a rapid and constant diffusion of the oxygen which is supplied at the bottom of the tank by highly efficient diffusers.**

**Experiments showed that fingerlings, the volume of which exceeded 50 per cent of that of the water used, were thus comfortably accommodated for periods of three to four hours. Over longer periods, large quantities of slime accumulated in the water, and caused the death of the fish, but we believe that, if necessary, the adjunction of a pump and filter to the tank would readily eliminate the slime.**

**A description is given of the equipment for the transportation of trout by plane and of the method of planting fish from the air.**

## RESPIRATION OF TROUT FINGERLINGS IN RELATION TO THE PROBLEM OF THEIR TRANSPORTATION IN CROWDED TANKS

The constantly increasing activity in the stocking of lakes and rivers, has given rise to a certain number of new problems in connection with the method of transporting fingerlings. That which we shall consider in this paper, concerns the minimum volume of water and oxygen necessary for a certain given number of trout, to keep them in good condition during the long hours required for ordinary distribution to the lakes of the Province. We shall benefit economically if, on every stocking trip by truck or plane, we carry the greatest possible number of trout, for in this way we reduce the number of trips, and consequently, the cost of distribution, to a minimum.

The method of transportation currently employed, requires the use of tanks of from 8 to 10 gallons capacity, although occasionally, larger ones are employed. This method has, so far, been satisfactorily effective for the transportation of fish, particularly since the use of oxygen has increased the radius of distribution without one or more changes of water. However, this system does not permit the organization of large circuits, in the course of which a truck could effect the stocking of fifteen or twenty lakes without returning to the fish-culture station for additional loads.

On the other hand, the use of a plane offers interesting possibilities by permitting direct and rapid access to a large number of lakes, which otherwise would be difficult to reach. However, the capacity of a plane limits the volume and weight of each load, and it would be justifiable to transport fish by plane only if a satisfactory number of trout were carried.

In any event, the following problem must be solved to insure an economical transportation of fish, either by truck or plane: What is the maximum number of trout that it is possible to carry in a given volume of water, over long distances to the remote lakes to be stocked, without having recourse to a change of water? The latter condition is imposed by the fact that it is impossible to change the water during the course of a trip by plane, and also because it is, more often than not, impossible for the truck driver, while en route, to find water of a purity and temperature suitable for trout.

The diffusion of oxygen in water permits, as we can easily understand, a considerable increase in the number of trout which may be placed in a tank. It seems very logical to think that this increase would be limited only by the speed of diffusion of oxygen in the water, and that the solution of the problem which faces us, would, therefore, depend on the efficiency of the diffusers and on the volume of oxygen we deliver to them.

The experiments which we performed to test this hypothesis were carried out in an aquarium of 50 litres capacity, converted for this purpose to a square tank 1 metre in height and with a cross-section area of 500 square centimetres.

When we placed 400 trout (weighing 660 grams per 100 fish) in this aquarium full of water with 7.45 p.p.m. of dissolved oxygen and a temperature of 8.5° C., they turned on their backs in forty-five minutes from lack of oxygen in sufficient concentration. At this moment, the oxygen content was 3.1 p.p.m.

The injection of 500 cubic centimetres of oxygen per minute into the same aquarium, by means of two carbon diffusers, permitted a gradual increase in the number of trout from 400 to 600 to 1,000 to 1,500. It was possible to keep such numbers of trout without difficulty, since the speed of diffusion of oxygen in the water always remained above

**TABLE 1. OXYGEN CONTENT OF THE WATER IN P.P.M. IS NOT LOWERED TO A CRITICAL POINT, EVEN WITH AN INCREASED NUMBER OF FISH**

| Number of trout | Percentage of the trout volume to the volume of water | Water temperature (Centigrade) | Time in hours ½ | 1 | 2 |
|---|---|---|---|---|---|
| 400 | 6 | 7.45 | .... | 26.0 | 29.0 |
| 600 | 9 | 7.45 | 18.00 | 23.6 | ..... |
| 1,000 | 15 | 7.45 | 9.45 | 12.5 | 18.2 |
| 1,500 | 24 | 7.45 | 8.45 | 10.0 | 12.9 |

that of consumption by the fingerlings. For every experiment, the increase of oxygen content in the water, determined by periodical dosage, is shown in Table 1.

When the number of trout was increased to 2,000 they soon showed an abnormal agitation, and at the end of thirty-five minutes, seventy-five of them had turned on their backs, and thirty-four subsequently died. Nevertheless, the oxygen concentrations observed at this moment, at certain points of the tank, were greater than the minimum concentration limit to which previous experiments had proved the trout could have been exposed (about 3.1 p.p.m.). The concentrations of dissolved oxygen found at the moment the trout turned over were: 4.7 p.p.m. and 6.2 p.p.m. at the bottom, 8.5 p.p.m. at the center, and 6.8 p.p.m. at the surface of the aquarium. Furthermore, we knew that neither the pH nor the concentration of slime in the water had attained the limits which could explain the observed effect.

The transportation of a few hundred young trout, in tanks of from 8 to 10 gallons capacity, had shown us that they always remain at the bottom of the tank if all the conditions of temperature, oxygen concentration, etc., are normal. They use, effectively, only a small portion of the water that is placed at their disposal. The progressive increase in the number of trout placed in our aquarium had not changed this behavior. The trout huddled together in tight rows at the bottom of the aquarium. Under these conditions, the diffusion of oxygen in the water is very irregular, because of the unfavorable distribution of the fingerlings.

When the number of 2,000 trout was reached, the accumulation that crowded the lower part of the aquarium was such that we surmised that at certain points, all the oxygen must have been rapidly used up and exhausted without a chance of renewal, in spite of the active functioning of the diffuser. This oxygen depletion caused the premature exhaustion of a certain number of fingerlings.

However, it is well to note that an increase of delivery by the diffusers permitted us to continue our experiment with success. The more rapid diffusion obtained by using four diffusers, with a delivery capacity of 1,920 cubic centimetres a minute, allowed us to hold 2,000 trout successfully.

The most natural means of removing this difficulty seemed to be, not the increase in oxygen supply, but rather a provision for a more even distribution of the trout throughout all parts of the tank, by separating them into groups with shelves made of perforated metal (Figure 1). The perforations would permit easy, vertical circulation of oxygen to all levels. So divided into five groups of 400, the 2,000 trout, some of which had previously turned over at the end of thirty-five minutes, with the flow of 500 cubic centimetres of oxygen a minute, were now quite comfortable during a prolonged period, and, thanks to the delay that the shelves brought about in the ascent of the

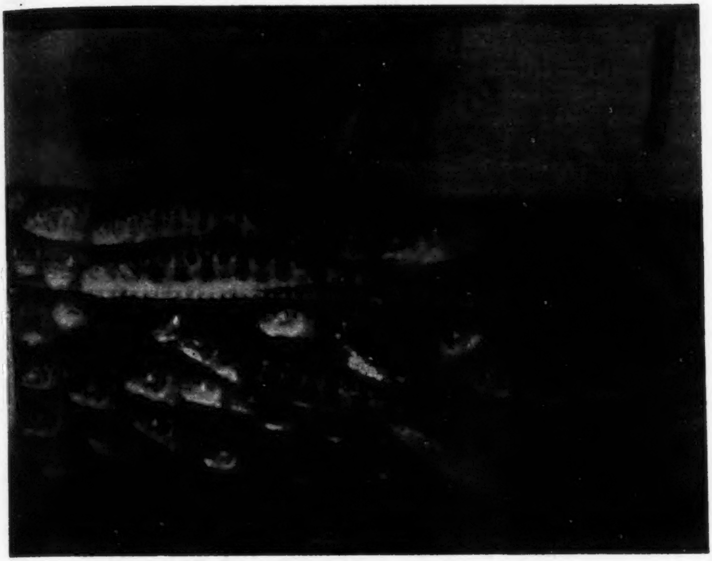

Fig. 1. Close-up view of fingerlings distributed in layers.

oxygen, the oxygen content was raised considerably. At the end of three hours, the oxygen concentration averaged 31 p.p.m. at the surface and 27 p.p.m. at the center of the aquarium, thus indicating that the speed of diffusion of oxygen in the water was still considerably greater than that of consumption by the trout.

This system of division in five compartments is not sufficient when applied to smaller trout whose weight is 145 grams per hundred. If 1,000 fingerlings are placed on each shelf, the 5,000 trout represent a volume of 7,250 cubic centimetres (18 per cent of the volume of water) against a total volume of 13,200 cubic centimetres (38 per cent of the volume of water) in the previous experiment with larger trout. Yet, in spite of an increase of oxygen to 9.2 p.p.m. at the end of one hour, and to 11.2 p.p.m. at the end of two hours, the experiment had to be interrupted because over 100 trout, of which 82 subsequently died, showed evident signs of exhaustion. But when we divided each one of the five compartments previously mentioned, into two smaller spaces, placing 500 trout in each, they seemed so comfortable and well that we were able to prolong the experiment beyond the period of time usually required for an ordinary delivery trip.

From these experiments and some others that cannot be related here, we reached the two following general conclusions: (a) The young fingerlings or the smaller fish must not only be given an adequate supply of oxygen by proper and effective diffusion, but they must be separated vertically in lots, the number of which must not exceed a certain limit. It seems that they are rapidly exhausted from the continuous struggle they exhibit when crowded in large numbers. (b) The larger fingerlings must also be separated in vertical lots, but, provided that the oxygen concentration in all parts of the tank is maintained to a sufficient level, they will survive easily in spite of a certain amount of huddling. The crowding should not, however, exceed a certain limit, which is determined by the size of the fish. When separated in this manner, by perforated shelves arranged in a vertical series, surprising numbers of fingerlings can be comfortably accommodated in a relatively small volume of water. The volume of the fish thus kept without loss or discomfort over periods of three to four hours exceeded in many experiments 50 per cent of the volume of the water in which they were maintained. The flow of oxygen does not necessarily have to be very high, due to the facility with which it diffuses, and because it is retarded in its ascent by the vertical shelves. Very efficient diffusers of the carbon type, giving off a steady stream of very fine bubbles of oxygen, are necessary.

It may be worth while pointing out that the slime, which the trout secrete continually, accumulates in the water and after a certain

**TABLE 2. THE SLIME IS QUITE UNIFORMLY DISTRIBUTED IN ALL PARTS OF THE AQUARIUM**[1]

| Volume of water and fish (litres) | Number of trout | Volume of 100 trout (cubic centimeters) | Percentage of the trout volume to the volume of water | Time in hours | Number of shelves | Oxygen consumed in p.p.m. | |
|---|---|---|---|---|---|---|---|
| 27 | 1,000 | 660 | 31 | 2¼ | 6 | Top shelf No. 1 | 9.6 |
| | | | | | | Shelf No. 2 | 8.9 |
| | | | | | | Shelf No. 3 | 9.0 |
| | | | | | | Shelf No. 4 | — |
| | | | | | | Shelf No. 5 | 7.8 |
| | | | | | | Bottom shelf No. 6 | 9.4 |
| 27 | 1,000 | 660 | 31 | 2¼ | 0 | Surface | 6.8 |
| | | | | | | Bottom | 6.8 |
| 27 | 1,000 | 660 | 31 | 2¼ | 0 | Surface | 6.9 |
| | | | | | | Bottom | 6.7 |
| 27 | 1,000 | 660 | 31 | 3½ | 0 | Surface | 9.0 |
| | | | | | | Bottom | 8.1 |

[1]Flow of oxygen was 500 cubic centimeters a minute and the water temperature was 8.4° C.

time attains such a concentration, that the water assumes a milky aspect. The amounts of oxygen consumed, determined with potassium permanganate, become large (see Table 2 for these concentrations).

The slime, even in such concentrations, is not dangerous for a limited period of three or four hours. Beyond these periods, the slime apparently disturbs the trout considerably and may cause the death of a number of them. In practice, we never had to consider the slime, because our trips lasted only two hours.

It is necessary, however, during long trips to eliminate this slime as rapidly as it is produced by the trout. We believe that the installation of an effective filter and a good pump, as auxiliaries to the transport tanks, would bring a quick and simple solution to this problem. The development of a method for the elimination of slime will be the objective of future research.

## Description of the Method Used for the Transportation of Fish by Airplane

In an earlier paper presented to this Society (Prévost, 1935), we

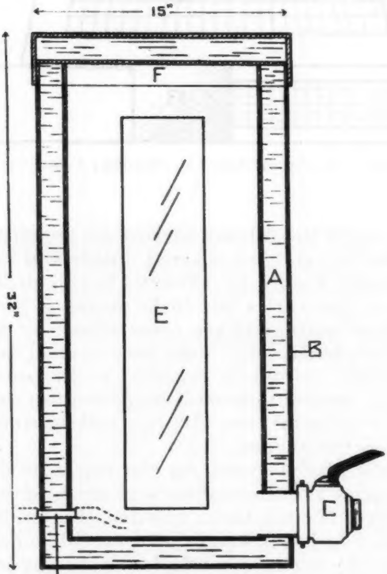


Fig. 2. Diagram of fish tank. A, balsa wood; B, tin; C, valve; D, metal tube; E, glass; and F, cover.

demonstrated that it is possible to drop young trout, from 3 to 5 inches in length, from an airplane flying at an altitude of 100 feet or more, without any ill effect either from the descent or the shock of landing. This knowledge is very valuable for the stocking of lakes which are as difficult to reach as most of the lakes in the Province of Quebec. At the present time a brief description will be given of the technique used in this method of distribution. First, it should be mentioned that it is not necessary to use a specially equipped hydroplane. A cabin-type craft, with a capacity of from 600 to 1,200 pounds, is quite suitable for the purpose.

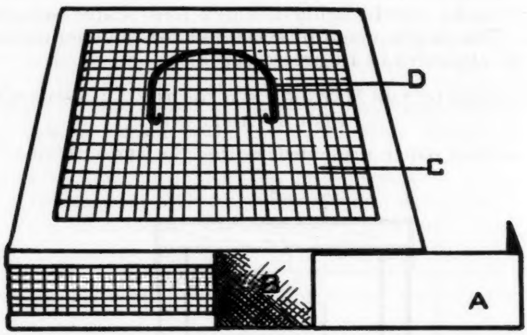


Fig. 3. Fish cage. A, sliding door; B, opening; C, screen; and D, handle.

The boxes in which the fish are carried are constructed from balsa wood (for insulation) and are covered, inside and out, with galvanized metal sheeting (Figure 2). Thanks to this insulation, the temperature of the water varies but little during a period of three to four hours. These containers are constructed, by preference, with square bases which make them more easy to load and, incidentally, less costly to build. Attention is called to the small window (E) which permits the constant observation of the fish during the course of a trip. Also, note metal tube (D) to which is attached the rubber tube which carries the oxygen.

The fish are not placed loosely in the reservoir described above, but, rather, in cages the dimensions and mesh of which are determined by the size of the fish being handled (Figure 3). These cages measure 1.5 or 2.75 inches in height, and are 10 inches square. They have an opening (B) in one side which is closed by means of a small sliding panel (A). The fish are placed in these cages by means of a funnel (Figure 4), and from nine to fifteen super-imposed cages are placed in a tank (Figure 5).

Fig. 4. Placing fish in cages.

Fig. 5. Super-imposed cages and tank.

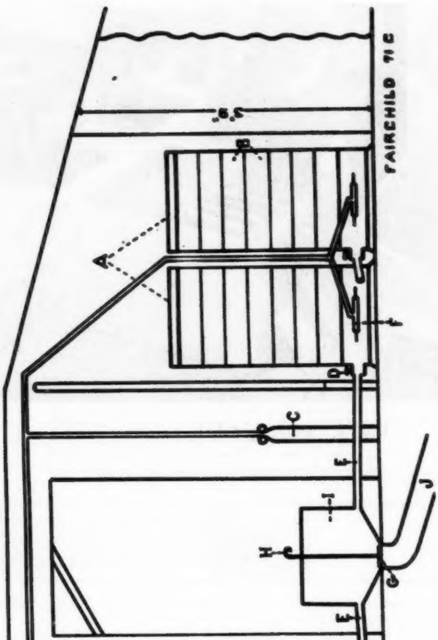


Fig. 6. Sagittal section of the hydroplane. Capacity: 1,200 pounds. A, tanks; B, cage; C, oxygen cylinder; D, valve; E, rubber tube; F, oxygen diffuser; G, plug; H, bar; I, funnel; and J, distributing pipe.

It was demonstrated in the first part of this paper that it is not possible to transport a large number of trout without the aid of oxygen. When the trout are planted from planes a supply of oxygen is usually carried in a small cylinder weighing 20 pounds. The flow of oxygen injected into each container is approximately 500 cubic centimetres per minute. This amount is quite sufficient to keep the water well saturated at temperatures ranging from 5° to 8° C.

The trout are released from the plane through a funnel which is constructed with a long curved outlet and which has a capacity of approximately 6 gallons (see Figure 6). This curved outlet is closed at its upper extremity by means of a plug which is attached to a long handle.

The procedure for dropping the fish in the lake is as follows: The valve (D) in the reservoir is opened and approximately one-half gallon of water is allowed to flow through the tube (E) and into the funnel (I) which, of course, is well plugged. Next a cage is removed from the reservoir (A) and the fish therein are transferred to the funnel. At a signal from the pilot the plug (G) is removed by means of the long handle (H) and the fish are allowed to flow through the pipe (J). At the next lake the same operation is repeated.

The maximum number of fish that can be transported has not yet been determined. However, the figures in Table 3 clearly indicate that the use of an airplane is justified, particularly if we consider our local conditions.

**TABLE 3. STATEMENT OF CONDITIONS TO BE MAINTAINED IN THE TRANSPORTATION OF TROUT FINGERLINGS BY PLANE, WITH ESTIMATES OF THE GREATEST NUMBER OF FISH THAT CAN BE CARRIED AND THE COST PER MILE WITH A PLANE WHOSE CAPACITY IS 600 LBS.**

| Item | Cage A (2.75 inches high) | Cage B (1.5 inches high) |
|---|---|---|
| Number of fish per cage | 200 to 400 | 400 to 600 |
| Weight per fish in grams | 5 to 7 | 2 to 4 |
| Number of cages per tank | 9 | 15 |
| Number of tanks | 3 | 3 |
| Total number of fish per trip | 5,400 to 10,800 | 18,000 to 27,000 |
| Water temperature in ° C. | 5° to 8° | 5° to 8° |
| Flow of oxygen in c.c. per minute per tank | 500 to 1,000 | 500 to 1,000 |
| Duration of trip in hours | 1 to 2 | 1 to 2 |
| Cost of plane per mile | $0.30 | $0.30 |

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# SUMMARY OF A FOUR-YEAR CREEL CENSUS ON FIFE LAKE, MICHIGAN

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ABSTRACT

A creel census has been taken on Fife Lake, Michigan, for four successive fishing seasons, 1934 to 1937 inclusive. The data indicate a constant decline in the catch of some species and a corresponding increase in the catch of others. The total take remained relatively constant from year to year; an increase of 92 per cent in fishing effort resulted in an increase in the take of only 16 per cent. Some correlation was found between the percentage of larger piscivorous fish and the size of pan fish in the catch.

## INTRODUCTION

The analysis of fishing intensity and yield in number of legal fish per acre from Fife Lake, Michigan, was determined from a creel census conducted during four successive seasons, extending from 1934 to 1937, inclusive. The methods used in the Fife Lake creel census were discussed in an earlier publication (Eschmeyer, 1936) and have been used throughout the investigation, with some modifications. Data for the first and second seasons were compared in a second report (Eschmeyer, 1937).

The census for the entire period was taken by crews of selected enrollees from the Fife Lake C. C. C. Camp. The men patrolled the shores and interviewed the anglers after they had concluded their fishing for the day. The census was operated from daylight to dark. Reports were obtained the next morning from the majority of the anglers who fished after dark. During the last year of the census, 1937, the census clerks appeared to be less capable than during previous years and adequate supervision by trained fisheries investigators was impossible. Therefore the data for the last summer probably are not as reliable as the information gathered during the three preceding years of the census.

The period covered by the creel census extended from June 25 to September 30 each year, except during the 1937 season, when the census was taken from June 25 to September 7. Therefore, the census represents only the summer fishing season, which is the period of greatest fishing intensity.

The number of anglers observed but not interviewed bore the following percentage relationships to the total number of anglers: 1934, 7 per cent; 1935, 2 per cent; 1936, 1 per cent; and 1937, 5 per cent. Anglers seen but not contacted are not included in the following discussion except as indicated. Where they were considered, it is assumed that their fishing conformed, in all respects, to the average fishing of anglers who were interviewed.

## General Data on the Fishing

The number of anglers contacted varied from 2,399 in 1934 to 4,821 in 1936 (Table 1). The number of fishermen for each of the four years was, respectively: 2,580, 3,685, 4,875, and 4,751, including those seen but not contacted. These numbers represent 3.5, 5.0, 6.6, and 6.4 fisherman-days per acre of lake surface. The increase in the number of anglers in 1935 and 1936 undoubtedly was due principally to an improvement in economic conditions, and the slight decrease in 1937 may be attributed to the numerous strikes and general labor uncertainties that occurred during the year. The fishing intensity on this resort lake is determined, in a large measure, by general economic conditions insofar as they are related to the money available for recreation.

TABLE 1. GENERAL DATA ON FISHING FOR FOUR SUMMER SEASONS ON FIFE LAKE, MICHIGAN

| Year | Number of fishermen | | | Total number of hours fished | Average number of hours per fisherman per day | Total number of fish caught | Average catch per fisherman per day | Average catch per hour | Average total length of fish (inches) |
|---|---|---|---|---|---|---|---|---|---|
| | Male | Female | Total | | | | | | |
| 1934 | 1,835 | 564 | 2,399 | 6,187.75 | 2.6 | 10,656 | 4.4 | 1.7 | 8.3 |
| 1935 | 2,831 | 763 | 3,594 | 8,971.50 | 2.5 | 11,375 | 3.2 | 1.3 | 8.1 |
| 1936 | 3,832 | 989 | 4,821 | 12,669.00 | 2.6 | 13,183 | 2.7 | 1.0 | 7.8 |
| 1937 | 3,655 | 846 | 4,501 | 11,843.25 | 2.6 | 11,495 | 2.6 | 1.0 | 8.7 |

The total catch of fish recorded varied in number between the extremes of 10,656 in 1934 and 13,183 in 1936. The catch per hour declined from 1.7 in 1934 to 1.0 in 1936 and 1937. The average size of fish decreased each year until 1937, when the average was somewhat higher than that for the previous year. The differences in average size may be related, in part, to changes in the species composition of the catch, although, as indicated later, the average length of individual species increased also.

## Trends in the Catch

A comparison of the species of fish caught during the four years of the census showed a change in the composition of the catch (Table 2). The total number of largemouth bass captured increased each year and the number of smallmouth bass decreased consistently. Bluegills increased in abundance during the first three years but slightly fewer were taken in 1937 than in 1936. In 1937, if the anglers from whom no reports were received had been considered, the bluegill catch probably would have been greater than in 1936. The num-

TABLE 2. NUMBER AND AVERAGE LENGTH OF FISH TAKEN IN FOUR SEASONS IN PIPE LAKE

| Species | 1934 Total number | 1934 Average total length (inches) | 1935 Total number | 1935 Average total length (inches) | 1936 Total number | 1936 Average total length (inches) | 1937 Total number | 1937 Average total length (inches) |
|---|---|---|---|---|---|---|---|---|
| Largemouth bass | 294 | 13.5 | 470 | 13.6 | 480 | 13.8 | 558 | 13.8 |
| Smallmouth bass | 992 | 12.3 | 782 | 13.1 | 673 | 12.6 | 619 | 13.1 |
| Bluegills | 1,970 | 7.2 | 3,696 | 7.0 | 5,189 | 6.7 | 4,966 | 7.2 |
| Sunfish | 1,016 | 6.8 | 1,418 | 6.7 | 1,611 | 6.5 | 1,945 | 6.9 |
| Yellow perch | 3.757 | 7.4 | 2,340 | 7.3 | 2,773 | 7.3 | 1,357 | 7.6 |
| Rock bass | 2,129 | 7.9 | 2,384 | 7.5 | 2,037 | 7.3 | 1,267 | 7.7 |
| Wall-eyed pike | 119 | 20.1 | 154 | 21.3 | 126 | 22.8 | 168 | 20.8 |
| Northern pike | 48 | 21.8 | 53 | 21.5 | 172 | 21.8 | 477 | 20.9 |
| Bullheads | 303 | 10.5 | 72 | 10.0 | 81 | 11.2 | 26 | 12.3 |
| Miscellaneous | 28 | — | 6 | — | 41 | — | 112 | — |
| Total | 10,656 | — | 11,375 | — | 13,183 | — | 11,495 | — |

ber of sunfish declined irregularly, wall-eyed pike increased irregularly, and northern pike were better represented during each succeeding season. In 1936 the catch of northern pike was 3.2 times as large as the number taken during the previous year and there was a further significant increase in 1937 as compared with 1936. A measure of the change in species composition of the catch that occurred between 1934 and 1937 is indicated by the following percentages, which have been rounded off to the nearest whole number:

| Species | 1934 | 1937 |
|---|---|---|
| Largemouth bass (*Huro salmoides*) | 3 | 5 |
| Smallmouth bass (*Micropterus dolomieu*) | 9 | 5 |
| Bluegill (*Lepomis macrochirus*) | 18 | 43 |
| Sunfish (*Lepomis gibbosus*) | 10 | 17 |
| Yellow perch (*Perca flavescens*) | 35 | 12 |
| Rock bass (*Ambloplites rupestris*) | 20 | 11 |
| Wall-eyed pike (*Stizostedion vitreum*) | 1 | 1 |
| Northern pike (*Esox lucius*) | 1 | 4 |
| Bullheads (*Ameiurus*, sp.) | 3 | —[1] |
| Miscellaneous | —[1] | 1 |

[1]Less than 0.5 per cent.

A decrease in the catch of one species was accompanied by an increase in the number captured of one or more of the remaining and perhaps competing species. Bluegills and sunfish together comprised only 28 per cent of the catch in 1934, but were responsible for 60 per cent of the total number of fish in 1937. Rock bass and perch together constituted 55 per cent of the total in 1934 and 23 per cent in 1937. Whether or not a close relationship exists between the trends in the catch and trends in the population is not known, but some correlation appears probable. The species composition of a population may change much more rapidly than is generally assumed.

A close correlation between the abundance of the larger piscivor-

TABLE 3. PERCENTAGE OF THE LARGER PISCIVOROUS FISH IN THE CATCH IN FIFE LAKE

| Species | 1934 | 1935 | 1936 | 1937 |
|---|---|---|---|---|
| Largemouth bass | 2.8 | 4.1 | 3.6 | 4.9 |
| Smallmouth bass | 9.3 | 6.9 | 5.1 | 5.4 |
| Wall-eyed pike | 1.1 | 1.4 | 1.0 | 1.5 |
| Northern pike | 0.5 | 0.5 | 1.3 | 4.1 |
| Total | 13.7 | 12.9 | 11.0 | 15.9 |

ous fishes (basses, wall-eyed pike, and northern pike) and the size of the pan fish (yellow perch, bluegills, sunfish, rock bass, etc.) is suggested (Tables 2 and 3). The average lengths of the pan fishes decreased slightly each year until 1937, when a significant increase in length was noted (Table 2). The percentage of larger piscivorous fish in the catch decreased each year until 1936; but the percentages increased again in 1937. The increase in abundance of northern pike from 58 in 1935 to 172 in 1936 and to 477 in 1937 is especially noteworthy.

## Number of Fish per Acre

The area of Fife Lake was assumed to be 800 acres in the computations of yield per acre for the first two years of the census. Dr. David S. Shetter and Mr. O. H. Clark of the Institute staff made a marginal survey of Fife Lake in April, 1938, and determined the area at that time to be 739 acres. Using this value and assuming that the fishermen not contacted had made average catches, the catches per acre during the four summer seasons (1934 to 1937, inclusive) were: 15.5, 15.8, 18.0, and 16,4, respectively. The fish were not weighed and therefore the catch in pounds per acre could not be determined.

## The Season's Catch

The total number of fish taken annually is more or less constant and appears to be independent of the fishing intensity. The number of fishermen and the total number of hours fished varied considerably during the four-year period, but the total catch fluctuated relatively little (Table 1). In 1936, the fishing intensity (hours fished, including estimated hours for those fishermen seen but not contacted) increased 92 per cent but the catch increased only 16 per cent.

This evidence suggests that only a limited portion of the fish population in lakes may be captured annually regardless of the fishing intensity. A similar situation was found in Howe Lake, which, although presumably fished out, still contained an average of from nine to ten legal-sized bass (larger than 10 inches) per acre (Eschmeyer, 1939). Likewise, it has been estimated that only about 8 per cent of the available legal fish were removed by angling from a group of southern Michigan lakes (Hazzard and Eschmeyer, 1938). No information was obtained concerning the percentage of the total population removed from Fife Lake by angling. The increase in total

catch and the increase in average length of the various species in 1937 are evidence that the number of fish taken was not influenced by the catch during previous years. The average length of fish of each species caught in 1937 was greater, or at least equal to, the average length in 1934 even though fishing was heavy during the intervening period. The number of pounds caught in 1937 undoubtedly was as great or greater than in any preceding year (1934 to 1936).

It seems probable that increased fishing intensity is correlated with a smaller catch per hour rather than with a decrease in the total population available to the angler.

Fishing usually is much better during the first few weeks of the summer than during the peak of the tourist season in late July and early August. The poorer fishing in mid-season generally is attributed to changes in water temperature, changes in the feeding habits of the fish, to a greater proportion of unskilled anglers, or to other unknown causes. The fact that a considerable percentage of the annual take has been removed by mid-season and that consequently more food should be available for the remaining fish, may be a very significant factor.

## Relationship between Stocking and the Angler's Catch

Definite information concerning the relationship of stocking to the subsequent catch is not available because the fish lengths were not recorded individually. The creel census card requested the average lengths of the fish of each species taken and the values tabulated probably were estimates rather than actual measurements. The distribution of age groups in the catch was not determined for this reason. The relationship of average age of the population available to the angler (as determined for a frequency distribution of actual length measurements) to artificial propagation could not be determinated because of the above deficiencies in the original data. It may be mentioned, however, that species that were not stocked (northern pike, sunfish and rock bass) fluctuated considerably in the total catch. The number of northern pike, for instance, increased from a total of 48 in 1934 to 477 in 1937.

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# PENNSYLVANIA'S SPRING CREEK PROJECT

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The Spring Creek Project consists of a fish farm, 1⅛ miles of a stream used as a controlled fishing area, and 900 feet of an artificial stream for women anglers only. It is located at Bellefonte, Centre County, Pennsylvania, in the exact geographic center of the State. The fish farm consists of three units, located within a radius of 3 miles. The Pleasant Gap unit is made up of a main hatchery building and ninety-eight rearing pools. A development that will add forty-nine ponds is now under construction. The Lower Spring Creek unit consists of 117 ponds and the Upper Spring Creek unit of 86 ponds, or a total of 201 ponds now in use and 49 under construction. In 1937, 147,058 pounds of fish from this fish farm were stocked in the public waters of the State. The food consumed over the same period totalled 596,936 pounds.

During 1932 and 1933, a wave of enthusiasm for stream restoration work swept through the Commonwealth of Pennsylvania. This type of work on fish conservation was new to all associated with the Fish Commission. The organized sportsmen and others were clamoring for advice on methods of construction. At the same time the Commissioners were desirous of securing additional property for fish-cultural purposes and the site of the present Spring Creek Project had been under observation for several years. Fortunately, it was suitable for both fish-cultural work and experimental stream-restoration development, and was purchased in the spring of 1933. The purchase included 1⅛ miles of Spring Creek.

Spring Creek is fed at intervals throughout its course by large limestone springs, which furnish a strong dry-season flow. It has its source in the Tussey Mountains, in Potter Township, Centre County, flows in a northwesterly and northeasterly direction and enters Bald Eagle Creek, near the town of Milesburg. The total length of the stream is approximately 24 miles and the total drainage area is about 146 square miles. The topography of the headwaters and middle basin consists of a rolling agricultural valley that becomes gorge-like in the lower basin and cuts through Bald Eagle Ridge. The rate of fall for the upper 3.5 miles is 28.6 feet per mile and the rate of the lower 16.5 miles is 18.4 feet per mile.

The Board's project is located about 12 miles from the source of the stream where the rate of fall is 19 feet per mile, and where the stream has a drainage area of approximately 120 square miles. Spring Creek has always been an outstanding trout stream, but the section selected for the stream-improvement work was sparsely populated with fish and was not frequented by the angler familiar with fishing conditions in

the stream. For about a year after the property was acquired, studies were made of stream improvement that had been conducted elsewhere and various types of improvement devices were constructed in miniature and tested in miniature waters to observe their effect on the stream. Actual improvement work was undertaken in the spring of 1934. It consisted of two Hewitt-type dams, 8 V-deflectors, 9 alternate deflectors, 2 log deflectors, 5 boulder dams, 15 submerged triangular log covers, 4 inverted V-deflectors and 3 stepping stone dams. This is a large number of stream improvement devices for a stretch of stream only 1⅛ miles long but it must be pointed out that the original intent was to install and demonstrate as many different types of devices as possible that were considered suitable for the improvement of Pennsylvania streams.

While the installation work was under way and shortly after it was completed, it was seen that not a sufficient number of individuals to justify the initial investment could be induced to visit the property for the sole purpose of observing the results. Those in charge then conceived the idea of furnishing another inducement in addition to the stream-restoration work to encourage visits to the area. This inducement was controlled fishing. In the spring of 1934 the improved section was heavily stocked with large trout and opened to the general public under certain rules and regulations. The project won the almost immediate approval of the anglers and has become so popular that it is now generally called the "Fisherman's Paradise." This particular kind of fishing seemed to appeal to the ladies, for they early expressed a desire to have a section of the stream set aside for their own enjoyment. Because of the short stretch of stream under control, it was not thought advisable to use the main stream for this purpose, and a bypass was cut for an artificial creek channel, paralleling the mountain side for a distance of 900 feet. This artificial creek was improved with devices similar to those in the main area and turned over to the "fair" sex under certain regulations. The artificial stretch of water serves a two-fold purpose. It is used by the ladies for angling while the project is open and during the fall and winter retains 40,000 eight to twelve-inch trout for distribution in the streams of the State the following spring.

With but few exceptions the regulations governing the conduct of the visiting anglers have not been changed since the original opening in 1934. No special fee is assessed for the privilege of fishing in the Project. The only requirement is a resident or non-resident fishing license. The project is enclosed with a woven wire fence and as the angler enters, his name, address and fishing license number are recorded at the entrance booth. He is then provided with a large identification button, bearing a number and the inscription, "Spring Creek Project." When he leaves the Project for the day, he checks out at the same booth, where he returns the identification button, and reports the number of fish caught and returned to the stream. A record is also

made of the species, length in inches and weight in ounces of the fish killed. Fishing starts in the morning and ends each evening at the sound of electric sirens located along the stream banks.

The following regulations were adopted during the 1938 season:

1. The open season extended from May 10 to July 9, both dates inclusive.

2. The project was open from 8:00 a. m. to 8:00 p. m. (Standard Time) or until the "Klaxon" was sounded.

3. No fishing was permitted on the project on Sunday.

4. Daily limit: 10 might be caught, but only 2 might be killed. The angler had to stop fishing after 2 fish had been killed.

5. Only artificial flies with barbless hooks or regular hooks with the barbs removed might be used. No spinners.

6. Fishing with, or possession of any live bait, angleworms, meat, liver, or any other bait, was a violation of the rules and regulations.

7. Size limit: All fish from the main stream under 10 inches in length and on the ladies' stream under 7 inches in length had to be carefully returned to the water.

8. All anglers who held a Pennsylvania fishing license were permitted to fish only five days during the season.

9. The dressing or cleaning of fish on the property was prohibited as all fish had to be weighed when checking out.

10. Positively no wading was permitted in the stream for any purpose.

11. No sinkers or weights of any kind were permitted.

12. Violators of any of the above rules and regulations were subject to a fine of twenty dollars ($20.00), confiscation of fishing equipment, revocation of fishing license, or all three if the Board deemed it advisable.

The increased interest of the public in the venture, since its inception, is illustrated by the statistics that have been compiled each year since the initiation of the project (Table 1).

**TABLE 1. STATISTICS OF FISHING ON THE SPRING CREEK PROJECT DURING THE YEARS 1934 TO 1937, AND DURING THE FIRST TWENTY-EIGHT DAYS OF THE 1938 SEASON**

| Year | Total number of fishermen | Total number of fish caught | Total number of fish killed | Average weight of fish killed (ounces) |
|---|---|---|---|---|
| 1934 | 2,952 | 4,729 | 2,472 | 8.8 |
| 1935 | 3,265 | 8,457 | 3,247 | 13.6 |
| 1936 | 6,513 | 8,467 | 2,663 | 15.1 |
| 1937 | 9,123 | 9,335 | 4,027 | 12.9 |
| 1938[1] | 8,739 | 7,028 | 4,101 | —— |

[1]First twenty-eight days of the season, only.

The question, "How many fish are actually caught or killed in proportion to the number stocked in the stream?", is asked frequently. This is difficult to answer definitely. The stream is not screened in any way; only the abundance of food and ideal shelter prevent the fish from leaving the Project. The main stream, both above and below the Project, is open to the public for fishing without any special restrictions. The number of trout caught above and below the Project, and the number of fish that left the restricted area, are not known. Also, because of the improvement devices installed in the stream, it would be difficult to take a census of the stream. However, judging from observation, while the fish are being fed, and from the amount of artificial food consumed daily, we believe that the stream now contains approximately 10,000 fish. A total number of 27,205 trout was planted during the interval between the time the project opened in 1934 and June 9, 1938. A total of 16,458 fish was caught during the same period. The difference between the original number planted and the total number caught, approximately 10,000, represents the number that remained in the stream.

During the first two seasons, the majority of the fish was stocked in the spring prior to the opening date and at intervals during the fishing season. It was noted that the fish that remained in the stream after the closing date stayed in the area and also that few fish left the improved section of the stream during the flood of March, 1936. As a result of these observations the fish for the 1937 season were stocked in August, 1936, and fish for the 1938 season in August and September, 1937.

By stocking the stream in late summer or early fall, the large trout can be kept in the stream at much less expense than in the hatchery pools. In addition to this, for the past two years, during spawning periods, the stream fish yielded about 1½ million eggs for hatchery purposes.

The Spring Creek Project, in addition to affording angling for 21,853 fishermen from 1934 to and including the 1937 season, has served as an out-of-doors laboratory for the Board of Fish Commissioners, and many interesting facts with reference to stream management have been noted. The theory that hatchery-reared or artificially-fed trout do not possess the game qualities of the so-called wild trout has been disproved. Outstanding anglers from many sections of the country maintain that the trout hooked on the Project show more gameness than do the average wild fish.

Records show that not all fishermen are fortunate enough to catch a fish. Some days the fish are not inclined to take the lure of even the most skilled anglers, yet the fisherman's knowledge that the waters are teeming with fish has to a great extent eliminated the often-heard complaint that the stream contains no fish. Trout on the Project are hooked, landed and released many times during each season, but the

mortality from this cause has been very low. It follows that in many waters, lightly-hooked fish can be landed and released, thus giving some other angler the opportunity of also obtaining some thrills from capturing the same fish. Further, small trout are permitted to grow to legal size before they are killed and used for food.

The present intense fishing in Pennsylvania streams will no longer permit the fish crop to be looked upon as so much food for the family table, but must be looked at from the standpoint of recreation only. The compulsory fly fishing in the Spring Creek area, plus the fact that the Board provides an instructor in casting and fly-tying at the Project to teach those interested in the arts, has had a very wholesome effect on the fishing methods in public waters.

While the people who use the Project, as a whole, show a fine spirit of sportsmanship and obey the rules, a sufficient number has been caught in the act of cheating, which indicates that many persons still believe in using any method for capturing fish, regardless of the law. This is proof that the money spent for the enforcement of conservation laws is still a necessity, and that a fertile field is open for further education in conservation.

The exceptionally large trout that are being taken at Spring Creek has created a demand throughout the state for the stocking of the trout streams with larger fish. Whether this is good or bad, cannot be said at this time. Many of the anglers prefer to catch one real large fish in preference to a number of smaller ones and their number is increasing. A few years ago anglers seemed to prefer quantity of fish to individual size.

# PROGRESS OF THE ROCK AND SHAD RESEARCH WORK AT THE CHESAPEAKE BIOLOGICAL LABORATORY[1]

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The rock, *Roccus lineatus,* and shad, *Alosa sapidissima,* investigations, which were started at the Chesapeake Biological Laboratory during the summer of 1936 (Truitt and Vladykov, 1936a), have been conducted for the purpose of obtaining biological information necessary for the establishment of sound conservation policies for these fishes. The rock, or striped bass, is the most important commercial and sport species of the Maryland waters of Chesapeake Bay (Truitt and Vladykov, 1936b). Unlike most of the marine and brackish-water fishes, it is present and supports a commercial fishery in the Chesapeake Bay at all seasons of the year. The shad differs greatly from the rock in its habits, and it is almost entirely a commercial species; hook-and-line fishing for shad is of minor importance and is permitted only after July 1, when the fish has finished spawning and is ready to return to the sea. The shad is very important commercially, although the fishing season for this form extends only from February 1 to June 10, due to its anadromous nature.

Information obtained on both rock and shad has included many determinations of lengths, weights, sex ratios, and gonad development. Counts of vertebrae, fin rays, and gill rakers have been made over a wide territory in an effort to detect the presence of local races. Scales and stomach contents from many fish have been collected for future study. An extensive tagging program has been conducted, as a part of the rock study, and a limited shad-tagging program was in operation during the seasons of 1937 and 1938.

The fish used in the course of the work reported here were taken both by commercial fishermen and by sportsmen. Rock observed from the commercial catches were taken by means of haul seines, fyke nets, gill nets, and pound nets; the last named device contributed the greatest part of the samples. Pound nets were used most commonly in the capture of shad samples studied, although at one point, Conowingo Dam, where conditions were unfavorable for the operation of other types of gear, the hoop dip net was employed. Young stages of shad and rock were collected by means of small hand seines from all sections of the Bay where they could be found.

Lengths and weights have been recorded and scale samples taken from over 13,000 rock and 2,000 shad. Counts of vertebrae, fin rays, and gill rakers for a racial study have been made on about 2,500 rock and 700 shad collected from Canada to North Carolina. The greatest number came from Chesapeake Bay. A large part of the scale samples

[1]Contribution No. 25 from the Chesapeake Biological Laboratory.

collected from the rock is to be mounted for age studies, the data from which will be supplemented by length-frequency distributions in an effort to arrive at the character and composition of the populations in the respective areas.

Detailed observations have been made on gonad development in 1,085 rock and approximately 300 shad. In addition to these detailed data, sex records were obtained for many thousands of individuals. Data were obtained also on the relation of body weight to gonad weight and on the location of spawning grounds.

The rock migration studies initiated by the Laboratory in 1936 have been continued through all seasons of the year; 2,056 fish have been tagged in Maryland, Virginia, and North Carolina. The more recent tagging operations have been carried on in order to gather data with which to supplement information previously reported (Vladykov and Wallace, 1937b) concerning the extent of migrations and the location of spawning areas.

Tagging experiments on shad, in which external markers were employed, were started in the spring of 1937. At that time, shad were tagged in a preliminary experiment designed principally to test the practicability of external tags for the study of the migrations of this species. The tag used was of the conventional double-disk type held in place by a nickel pin. Success followed this pioneering work and, during the 1938 season, 229 shad were tagged at the mouth of the Chesapeake to determine the percentage of capture, the location of the various spawning areas in the Bay, and the time required and paths followed by the fish to the spawning grounds after entering the Bay from the Atlantic Ocean.

A late-season experiment in tagging spent shad has been attempted in an effort (1) to determine whether or not these fish return to the same or to other areas in later years, (2) to gain information concerning migration routes of the fish after their return to the sea, (3) to obtain information on fishing intensity during the post-spawning period, (4) to learn whether or not repeated spawning takes place, and (5) to gather data concerning longevity of shad. These fish were tagged in the vicinity of Conowingo Dam, a part of a power project which cuts off many square miles of bottom of the Chesapeake headwaters in the Susquehanna River, where formerly vast spawning areas existed. Spent shad, which gather in numbers at the Dam, may be captured with comparative ease. In late June, 1938, 225 spent shad were marked by means of external tags similar to those described above. Sixty-two shad were marked with both internal and external tags in order to determine the relative efficacy of the two methods of identification. The internal tags, 32 by 8 by 0.75 millimeters, were made of highly colored celluloid.

Within the last three years detailed analyses have been made of 2,500 stomachs of rock. The material studied was taken from fish varying from a few ounces to 36 pounds in weight. Much information has

been accumulated on the food of the rock both as to kind and quantity consumed. Considerable light has been thrown on seasonal variations in feeding habits.

Direct observations on the feeding habits of rock have been obtained by means of feeding experiments that employed fish held in large concrete containers. These feeding experiments are proving highly instructive, since it has been possible to control the salinity, the time of feeding and the types of food, under temperature conditions that approximate those in the Bay. Young rock of the 1937 year-class taken shortly after the hatching period, have been carried through the different seasons with fine results. In size and general condition they now compare favorably with the native stock in open waters. Still other rock, of larger size, have thriven in captivity and developed normally as indicated by comparisons with members of the same year-class, now 4 years old, found in the Bay.

In addition to the great number of analyses made on the food of rock, about 700 stomachs have been collected and preserved from shad taken from Canadian waters, from the Hudson River, New York, from Delaware Bay, and from Chesapeake Bay in both Maryland and Virginia. Approximately two-thirds of the stomachs came from Chesapeake Bay. It is planned that a much larger number of stomachs, collected over a wider territory, will be accumulated.

The Laboratory's studies on rock and shad have suffered from the lack of statistical data on past catches. However, there have been located a few commercial fishermen and fish dealers who have complete records of their catches for many years. Through the cooperation of the owners of those records, certain catch data have been borrowed for the purpose of analysis, a task now almost completed. It is felt that, while the data are not abundant, they do offer a cross section of the industry of the past, and thus serve as a background for conclusions that may be drawn from data accumulated in more recent years relative to periodical fluctuations, fishing intensity, and brood-stock abundance.

In the course of this work, the question has arisen as to the population of rock that could be maintained under the food and the physical conditions of Chesapeake Bay. One of the most abundant year-classes ever produced in these waters was that of 1934. Although no records on the abundance of forage fish for rock are available prior to 1935, there was a big supply of food present during the peak of the commercial production of the 1934 year-class (1935 and 1936). However, in 1937, the supply of the most important food item, the anchovy (*Anchoviella mitchilli*) was greatly reduced. Much further study is planned concerning the relationship between year-classes and environmental factors, including food, in order to gain a clearer conception of the necessary brood-stock level that should be maintained.

At the time tagging experiments were started on the shad in the spring of 1937, about ninety fish were marked in an effort to deter-

mine the practicability of external tags for this fish. The large percentage of the tags returned over a period of several months, and the favorable results obtained from tagged fish held in tanks, demonstrated that tags can be used effectively, at least for a period up to two years. Returns were received from approximately 30 per cent of the fish tagged in the more extensive 1938 operations. Possibly because of the short lapse of time since the tagging of the spent shad at the Conowingo Dam was undertaken, very few returns have been received. Much more extensive work with both internal and external tags on spent fish is planned for the season of 1939. This experiment may yield information concerning possible repetition of spawning, longevity, and the movements of adult shad.

External tags have proven effective for the study of shad movements, at least during a single season. The tagging showed that fish marked near the ocean did not proceed immediately to the spawning grounds of the upper Chesapeake Bay and its tributaries. On the contrary, these fish required more than three weeks to reach the spawning grounds. Tag returns, in many instances, indicated that a portion of a school may move over an area of only a few square miles for as many as fifteen or twenty days. Usually there is a difference of from twenty to thirty days between the early run of shad in the lower and upper sections of the Bay.

Other phases of the shad investigation, such as the determination of length distributions, length-weight relationship, the analysis of stomach contents, and gill-raker counts, though of considerable value, have been considered as preliminary in nature. Indications of a possible relationship between Chesapeake shad and those in more remote waters (Vladykov and Wallace, 1937a) point to the necessity of a more comprehensive coast-wise study of this fish. This wider problem is now being attacked by the U. S. Bureau of Fisheries, and the program of the Chesapeake Biological Laboratory for the investigation of shad in the Chesapeake Bay area has become part of the more general program put in operation by the Bureau. All of the data gathered and facilities available, are being placed at the disposal of the Bureau. Certain phases of the larger program that can well be conducted locally are to be continued as a part of the Laboratory's program. The researches on the rock, too, are to be coordinated with the work done by the Bureau and certain state agencies.

Recent studies on the rock and shad have added to the volume of biological and economic information concerning these very important Chesapeake fishes. The relation of age and size to sexual maturity in rock has been determined for Chesapeake Bay, and the major spawning grounds have been located. The value of counts of vertebrae, gill rakers, and fin rays of dorsal, anal and pectoral fins has been determined in connection with racial studies. The existence of various races of shad and rock in the Chesapeake has been established, while tagging operations have contributed to a better understanding

of the movements of rock in the Bay, and to a partial understanding of the movements of fish, of local origin, northward along the Atlantic Coast to form a large part of the annual supply of several other states. These findings, and the fact that many different size limits exist in several states in which the rock is found, suggest the need for critical analyses of current conservation practices, and point to the desirability of complete cooperation on the part of the states sharing the rock fishery in order to insure more stable populations.

## Acknowledgments

Dr. V. D. Vladykov, formerly Fishery Biologist of the Chesapeake Biological Laboratory, organized the program in Chesapeake Bay, and carried it forward during 1936 and 1937. Mr. R. A. Nesbit of the U. S. Bureau of Fisheries offered valuable suggestions and cooperated in certain phases of the work. A number of fishermen and fish dealers loaned their catch and purchase records, furnished fish, and returned tags, especially A. W. Woodford and Company, Mr. George Harrison, Captains Buck Richardson, Carrol Jackson, Herman Harrison, Jim Price, Harrison Woolford, Harvey Mister and L. S. Taylor. Captain Henry Kopp assisted in the care of impounded experimental fish. The Conservation Department of Maryland, the Commission of Fisheries of Virginia, the Game and Fish Commission of Delaware, the Division of Game and Inland Fisheries of North Carolina, and the U. S. Bureau of Fisheries provided liberal cooperation and assistance.

## Literature Cited

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Vladykov, V. D., and D. H. Wallace

1937a. Remarks on populations of the shad (*Alosa sapidissima*) along the Atlantic Coast region. Trans. Am. Fish. Soc., Vol. 67, 1937, pp. 52-66.

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# APPENDIX

# AMERICAN FISHERIES SOCIETY
## Organized 1870

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### Certificate of Incorporation

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We, the undersigned, persons of full age and citizenship of the United States, and a majority being citizens of the District of Columbia, pursuant to and in conformity with sections 599 to 603, inclusive, of the Code of Law for the District of Columbia, enacted March 3, 1901, as amended by the acts approved January 31 and June 30, 1902, hereby associate ourselves together as a society or body corporate and certifying in writing:

1. That the name of the Society is the American Fisheries Society.

2. That the term for which it is organized is nine hundred and ninety-nine years.

3. That its particular business and objects are to promote the cause of fish culture; to gather and diffuse information bearing upon its practical success, and upon all matters relating to the fisheries; to unite and encourage all interest of fish culture and the fisheries; and to treat all questions of a scientific and economic character regarding fish; with power:

(a) To acquire, hold and convey real estate and other property, and to establish general and special funds.

(b) To hold meetings.

(c) To publish and distribute documents.

(d) To conduct lectures.

(e) To conduct, endow, or assist investigation in any department of fishery and fish-culture science.

(f) To acquire and maintain a library.

(g) And, in general, to transact any business pertinent to a learned society.

4. That the affairs, funds and property of the corporation shall be in general charge of a council, consisting of the officers and the executive committee, the number of whose members for the first year shall be seventeen, all of whom shall be chosen from among the members of the Society.

Witness our hands and seals this 16th day of December, 1910.

| | |
|---|---|
| Seymour Bower | (Seal) |
| Theodore Gill | (Seal) |
| William E. Meehan | (Seal) |
| Theodore S. Palmer | (Seal) |
| Bertrand H. Roberts | (Seal) |
| Hugh M. Smith | (Seal) |
| Richard Sylvester | (Seal) |

Recorded April 16, 1911.

# CONSTITUTION AND BY-LAWS

OF THE

# AMERICAN FISHERIES SOCIETY

(As amended September 4, 1936)

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## ARTICLE I

### Name and Object

The name of this Society shall be American Fisheries Society.

The objects of this Society shall be to promote the cause of fish culture and its allied interests; to gather and diffuse information on all questions pertaining to fish culture, fish, and fisheries; and to unite and encourage those interested in fish culture, and fisheries problems.

## ARTICLE II

### Membership

The membership of this Society shall be classified as follows: Active, Club, Libraries, State, Patron, Honorary, and Corresponding.

*Active Members.*—Any person may upon a two-thirds vote of the members present at any regular annual meeting and upon the payment of one year's dues become an active member of this Society. The annual dues of active members shall be three ($3.00) dollars per year, payable in advance. Any active member may upon payment of fifty ($50.00) dollars become exempt from the payment of annual dues though retaining the privileges of active membership for the duration of his life.

*Club Members.*—Any sporting or fishing club or society, or any firm or corporation, upon a two-thirds vote of the members present at any regular meeting and upon the payment of one year's dues, may become a club member of this Society. The annual dues of club members shall be five ($5.00) dollars per year.

*Libraries.*—Libraries may be admitted to membership upon a two-thirds vote of the members present at any regular meeting and the payment of one year's dues. The annual dues for libraries shall be two ($2.00) dollars per year.

*State Memberships.*—Any state, provincial or federal department of the United States, Canada or Mexico may become a state member of this Society upon a two-thirds vote of the members present at any regular meeting and the payment of one year's dues. The annual dues for State memberships shall be twenty ($20.00) dollars per year.

*Patrons.*—Any person, society, club, firm or corporation, on approval of the Executive Committee and the payment of fifty ($50.00) dollars or more, may become a patron, and shall be listed in all the published membership lists of the Society.

*Honorary and Corresponding Members.*—Any person may be made an honorary or corresponding member of this Society upon a two-thirds vote of the members present at any regular annual meeting of the Society. The President of the United States, the Governors of the several states, and the Secretary of Commerce of the United States, the Governor-General of Canada, the Lieutenant-

Governors of the several Canadian provinces, and the Dominion Minister in Charge of Game and Fisheries shall be honorary members of this Society while occupying their respective official positions.

*Election of Members between Annual Meetings.*—The President, Secretary and Treasurer of the Society are hereby authorized to act upon all applications for memberships received while the Society is not in session.

*Rights and Duties of Members.*—Active members in good standing only shall have the right to vote at regular or special meetings of the Society. Any member is held to be in good standing whose dues are not more than one year past due. In case of non-payment of dues for one year, proper notice shall be given the member by the Treasurer in writing, and if such member remains delinquent one month from the date of such notice, his name shall be dropped from the roll of the Society. Such delinquent member, having been dropped for non-payment of dues, shall be ineligible for election as a new member for a period of one year, except upon payment of arrears and current dues. Each member of the Society in good standing, except honorary members, shall receive one copy of the annual volume of Transactions.

*Quorum.*—Twenty voting members shall constitute a quorum for the transaction of business at annual or other meetings of the Society.

## ARTICLE III

### Funds

*Current Fund.*—All moneys received from the payment of dues of active members, club members, libraries, life members, state members, sale of Transactions, contributions thereto, and from any miscellaneous sources, shall be credited to the Current Fund of the Society and shall be paid out only on vouchers regularly approved by the President and Secretary.

*Permanent Fund.*—The President, Secretary and Treasurer shall be the Trustees of the Permanent Fund. All moneys received from patrons, bequests and contributions thereto shall be credited to the Permanent Fund of the Society. Such fund shall be invested by the Treasurer in such manner as may be approved by the trustees of such fund. The members of the Society shall, at each annual meeting, determine the disposition of interest accruing from such investment.

## ARTICLE IV

### Officers

The officers of this Society shall be a president, a first vice-president, and a second vice-president, all of whom shall be elected for the term of one year and shall be ineligible for reelection to the same office until a year after the expiration of their terms; a secretary, a treasurer, a librarian, and five vice-presidents, one to be in charge of each of the following divisions or sections:

1. Fish Culture.
2. Commercial Fishing.
3. Aquatic Biology and Physics.
4. Angling.
5. Protection and Legislation.

The officers specified above, and the president of the previous year, shall form

an Executive Committee* with authority to decide the policies of the Society and to transact such business of the Society as may be found necessary. The Executive Committee is authorized to fill from the membership any vacancies that may occur in any offices between meetings. A majority of the Executive Committee shall constitute a quorum.

Only members in good standing who are in attendance or have been in attendance at one of the two immediately preceding meetings shall be eligible for election to the offices listed above and for appointment to any committee, except the members of the Committee on Common and Scientific Names of Fishes.

The officers shall be elected by a majority vote at a regular meeting, a quorum being present.

No officer of this Society shall receive any salary or compensation for his services and no allowances shall be made for clerical services except by vote of the Society at regular annual meetings.

*Duties of Officers.*—The President shall preside at the regular and all special meetings of the Society and shall be ex-officio chairman of the Executive Committee.

The first Vice-President shall act in the place of the President in case of absence or inability of the latter to serve.

The Secretary shall keep the records of the Society, conduct its correspondence, promote its membership, and arrange for regular and special meetings. The Secretary shall also attend to the publication and distribution of the annual issuance of Transactions.

The Treasurer shall receive and collect all dues and other income of the Society, shall have the custody of its funds and pay all claims which have been duly approved. The Treasurer shall furnish a bond in the sum of seven thousand, five hundred ($7,500) dollars to be approved by the Executive Committee and to be paid for by the Society. The offices of Secretary and Treasurer may be occupied by the same person.

The Librarian shall have the custody of the library of the Society, including its permanent records and printed Transactions, and shall have charge of the sale of surplus copies of such Transactions.

The Vice-President of each division shall become conversant with the subject of his division and present a report on it at the regular meeting placing emphasis upon developments during the past year.

Committee members shall cooperate in performing the functions of their appointments and render reports as directed by the President.

## ARTICLE V

### STANDING COMMITTEES

The standing committees shall be Executive; Foreign Relations; Common and Scientific Names of Fishes; and Publications. The Committee on Publications shall be appointed by the President. The Executive Committee shall be selected as provided for by Article IV.

The Committee on Foreign Relations shall be composed of seven members selected by the nominating committee for election, and its duties shall be to exchange ideas pertaining to the various phases of fisheries administration, biology, including fish culture, with foreign fisheries biologists, conservation and fisheries administration officials, fish-culturists or aquicultural societies. A report based on such exchange should be presented at each regular meeting.

The Committee on Common and Scientific Names for Fishes shall be composed of seven members selected by the nominating committee for election. Its duties shall be to establish and maintain in the files of the Librarian of this Society a

*The Council was discontinued and the Executive Committee enlarged by Amendment to By-Laws, September 11, 1935.

correct check list of the species of fishes occurring in the waters of the United States and Canada. This list should contain both scientific and common names.

The Committee on Publications shall be composed of five members, and its duties shall be to select and edit manuscripts submitted for publication. Papers shall be submitted ready for publication within thirty days after the close of the regular meeting. Such papers, together with the minutes of the regular and special meetings and the reports of the various divisions and committees, shall be published in an annual volume which shall be numbered in series with previous volumes and entitled: TRANSACTIONS OF THE AMERICAN FISHERIES SOCIETY.

## ARTICLE VI

### Meetings

The regular meeting of the Society shall be held once a year, the time and place to be decided upon at the preceding meeting, or, in default of such action, by the Executive Committee. Special meetings shall be called by the President upon approval of a majority of the Executive Committee.

## ARTICLE VII

### Order of Business

1. Call to order by the President.
2. Roll call of members.
3. Application for memberships.
4. Reports of officers:
   a. President
   b. Secretary
   c. Treasurer
   d. Vice-Presidents of Divisions
   e. Standing Committees
   f. Special Committees
5. Committees appointed by the President:
   a. Committee of five on nomination of officers and standing committees for the ensuing year.
   b. Committee of five on time and place of next meeting.
   c. Committee of five on resolutions.
   d. Auditing committee of three.
   e. Committee of three on program.
   f. Committee of three on publicity.
   g. Committee of five on publications.*
6. Reading of papers and discussions of same. In the reading of papers preference shall be given to the members present.
7. Miscellaneous business.
8. Adjournment.

## ARTICLE VIII

### Changing By-Laws

The By-Laws of the Society may be amended, altered or repealed by a two-thirds vote of the members present at any regular meeting, provided at least twenty-five members are present at said regular meeting.

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*A resolution adopted August 24, 1937 established a staggered committee of five and provided that each succeeding President shall appoint one new member for a term of five years and designate the Chairman of the Committee.

# AMERICAN FISHERIES SOCIETY

## LIST OF MEMBERS
(Showing Year of Election to Membership)

### HONORARY MEMBERS

The President of the United States.
The Secretary of Commerce of the United States.
The Governors of the several States.
The Governor General of Canada.
The Lieutenant-Governors of the several Canadian Provinces.
The Dominion Minister in Charge of Game and Fisheries.
'08 Antipa, Prof. Gregoire, Inspector-General of Fisheries, Bucharest, Roumania
'06 Besana, Giuseppe, Lombardy Fisheries Society, Via Rugabello 19, Milan, Italy
'09 Blue Ridge Rod and Gun Club, Harper's Ferry, W. Va.
'04 Denbigh, Lord, London, England.
'09 Nagel, Hon. Chas., St. Louis, Mo.
'08 Nordqvist, Dr. Oscar Fritjof, Superintendent of Fisheries, Lund, Sweden.

### PATRONS

'14 Alaska Packers Association, San Francisco, Calif.
'15 Allen, Henry F. (Agent Crown Mills), 210 California St., San Francisco, Calif.
'15 American Biscuit Co., 815 Battery St., San Francisco, Calif.
'15 American Can Co., Mills Building, San Francisco, Calif.
'15 Armour & Co., Battery and Union Sts., San Francisco, Calif.
'15 Armsby, J. K., Company, San Francisco, Calif.
'15 Atlas Gas Engine Co., Inc., Foot of 22nd Avenue, Oakland, Calif.
'15 Balfour, Guthrie & Co., 350 California St., San Francisco, Calif.
'15 Bank of California, N. A., California and Sansome Sts., San Francisco, Calif.
'15 Bloedel-Donovan Lumber Mills, Bellingham, Wash.
'15 California Barrel Co., 22d and Illinois Sts., San Francisco, Calif.
'15 California Door Co., 43 Main St., San Francisco, Calif.
'15 California Stevedore & Ballast Co., Inc., 210 California St., San Francisco, Calif.
'15 California Wire Cloth Company, San Francisco, Calif.
'15 Caswell, Geo. W., Co., Inc., 503-4 Folsom St., San Francisco, Calif.
'15 Coffin-Redington Co., 35-45 Second St., San Francisco, Calif.
'15 Columbia River Packers Association, Astoria, Ore.
'15 Crane Co., C. W. Weld, Mgr., 301 Brannon St., San Francisco, Calif.
'15 First National Bank of Bellingham, Bellingham, Wash.
'15 Fuller, W. P., & Co., 301 Mission St., San Francisco, Calif.
'15 Grays Harbor Commercial Co., Foot of 3d St., San Francisco, Calif.
'15 Jones-Thierbach Co., The, Battery and Merchant Sts., San Francisco, Calif.
'15 Knapp, The Fred H., Co., Arcade-Maryland Casualty Building, Baltimore, Md.
'15 Linen Thread Co., The, W. A. Barbour, Mgr., 443 Mission St., San Francisco, Calif.
'15 Morrison Mill Co., Inc., Bellingham, Wash.
'15 Morse Hardware Co., Inc., 1025 Elk St., Bellingham, Wash.
'15 Pacific Hardware & Steel Co., 7th and Townsend Sts., San Francisco, Calif.
'15 Pacific States Electric Co., 575 Mission St., San Francisco, Calif.
'15 Pope and Talbot, Foot of 3d St., San Francisco, Calif.

'15 Puget Sound Navigation Co., Seattle, Wash.
'15 Ray, W. S. Mfg. Co., Inc., 216 Market St., San Francisco, Calif.
'15 Schmidt Lithograph Co., 2d and Bryant Sts., San Francisco, Calif.
'15 Schwabacher-Frey Stationery Co., 609-11 Market St., San Francisco, Calif.
'15 Sherwin-Williams Co., The, 454 Second St., San Francisco, Calif.
'15 Ship Owners' and Merchants' Tug Boat Co., Foot of Green St., San Francisco, Calif.
'15 Smith Cannery Machine Co., 2423 South First Avenue, Seattle, Wash.
'15 Standard Gas Engine Co., Dennison and King Sts., Oakland, Calif.
'15 Standard Oil Co. of California, Standard Oil Building, San Francisco, Calif.
'15 U. S. Rubber Co. of California, James B. Brady, Gen. Mgr., 2nd and Folsom Sts., San Francisco, Calif.
'15 U. S. Steel Products Co., Rialto Building, San Francisco, Calif.
'15 Wells Fargo National Bank of San Francisco, Montgomery and Market Sts., San Francisco, Calif.
'15 Western Meat Co., 6th and Townsend Sts., San Francisco, Calif.
'15 White Bros., 5th and Brannon Sts., San Francisco, Calif.

## LIFE MEMBERS

'12 Barnes, Ernest, Fisheries Experiment Station, Wickford, R. I.
'00 Beeman, Henry W., New Preston, Conn.
'13 Belding, Dr. David L., 80 East Concord St., Boston, Mass.
'80 Belmont, Perry, 1618 New Hampshire Ave., Washington, D. C.
'97 Birge, Dr. E. A., University of Wisconsin, Madison, Wis.
'04 Buller, A. G., Pennsylvania Fish Commission, Corry, Pa.
'12 Buller, Nathan R., Pennsylvania Fish Commission, Harrisburg, Pa.
'26 Cary, Guy, 55 Wall St., New York, N. Y.
'11 Cleveland, W. B., Burton, Ohio.
'04 Coker, Dr. Robert E., University of North Carolina, Chapel Hill, N. C.
'01 Dean, Herbert D., Northville, Mich.
'15 Folger, J. A., Howard and Spencer Sts., San Francisco, Calif.
'12 Fortmann, Henry F., 1007 Gough St., San Francisco, Calif.
'26 Goelet, Robert W., 18 East 47th St., New York, N. Y.
'22 Grammes, Charles W., Hamilton Park, Allentown, Pa.
'03 Gray, George M., Marine Biological Laboratory, Woods Hole, Mass.
'23 Grey, Zane, Altadena, Calif.
'28 Hall, W. A., Co., Gardiner, Mont.
'10 Hopper, George L., Havre De Grace, Md.
'23 Kienbusch, C. O., 12 E. 74th St., New York, N. Y.
'22 Kulle, Karl C., Suffield, Conn.
'26 Lackland, Sam H., 69 So. Ann St., Mobile, Ala.
'23 Lloyd Smith, Wilton, 63 Wall St., New York, N. Y.
'26 Low, Ethelbert I., 256 Broadway, New York, N. Y.
'15 Mailliard, Joseph, 1815 Vallejo St., San Francisco, Calif.
'99 Morton, W. P., 105 Sterling Ave., Providence, R. I.
'16 Nelson, Charles A. A., Lutsen, Minn.
'07 Newman, Edwin A., 4205 8th St., N. W., Washington, D. C.
'31 Nicholas, E. Mithoff, 20 S. 3d St., Columbus, Ohio.
'10 Osburn, Prof. Raymond C., Ohio State University, Columbus, Ohio.
'04 Palmer, Dr. Theodore S., 1939 Biltmore St., N. W., Washington, D. C.
'10 Radcliffe, Dr. Lewis, 5600 32nd St., N. W., Washington, D. C.
'05 Safford, W. H., 229 Wing St., S., Northville, Mich.
'00 Thompson, W. T., 121 N. Willson, Bozeman, Mont.
'13 Timson, William, Alaska Packers' Association, San Francisco, Calif.
'12 Townsend, Dr. Charles H., New York Aquarium, New York, N. Y.
'11 Valette, Luciano H., Echevarria F. C. S., Buenos Aires, Argentina, S. A
'22 Walcott, Frederic C., State Office Bldg., Hartford, Conn.
'98 Ward, Dr. Henry B., 1201 Nevada St., Urbana, Ill.
'97 Wood, Colburn C., Box 355, Plymouth, Mass.

## ACTIVE MEMBERS

'16 Adams, Dr. Charles C., State Museum, University of the State of New York, Albany, N. Y.
'35 Adams, Harry E., U. S. Forest Service, Milwaukee, Wis.
'33 Adams, Milton P., 638 Sunset Lane, East Lansing, Mich.
'13 Adams, William C., Dept. of Conservation, Albany, N. Y.
'29 Ainsworth, A. L., Tuxedo Fisheries, Tuxedo Park, N. Y.
'33 Albert, W. E., Jr., Lansing, Iowa.
'31 Aldrich, A. D., 2879 East Archer, Tulsa, Okla.
'34 Alexander, George J., Parliament Bldgs., Victoria, B. C., Canada.
'36 Allen, Edward W., Northern Life Tower, Seattle, Wash.
'29 Allen, William Ray, Dept. of Zoology, University of Kentucky, Lexington, Ky.
'32 Allen, Dr. William S., P. O. Box 7, Sherbrooke, P. Q., Canada.
'26 Alm, Dr. Gunnar, Commissioner of Freshwater Fisheries, Lantbruksstyrelsen, Stockholm, Sweden.
'33 Anderson, Albin, 376 E. Maryland St., St. Paul, Minn.
'08 Anderson, August J., Box 704, Marquette, Mich.
'35 Anderson, Herman, Route 1, Iesaquah, Wash.
'33 Anderson, Wendell A., Woodruff, Wis.
'24 Annin, Harry K., Spring Street, Caledonia, N. Y.
'14 Annin, Howard, Van Cortland Ave., Ossining, N. Y.
'37 Atkinson, Clinton E., Westminster Trust Bldg., New Westminster, B. C., Canada.
'29 Atkinson, C. J., Fisheries Dept., Ottawa, Ont., Canada.
'36 Atwood, Earl L., 213 S. Charter St., Madison, Wis.
'36 Babcock, James A., Lake Wapello, Drakesville, Iowa.
'32 Baer, Harry D., U. S. Fisheries Station, Quinalt, Wash.
'36 Bailey, Reeve M., Dept. of Zoology and Entomology, Iowa State College, Ames, Iowa.
'32 Bailliere, Lawrence, Stoutland, Mo.
'36 Baird, John C., 218½ W. Walnut, Springfield, Mo.
'27 Baker, Clarence, 2 South Carroll St., Madison, Wis.
'36 Baker, Dr. Clinton L., % Southwestern, Memphis, Tenn.
'15 Balch, Howard K., 110 E. Seeboth St., Milwaukee, Wis.
'37 Ball, Robert, Worthington, Ohio.
'23 Bangham, Dr. Ralph V., Wooster College, Wooster, Ohio.
'37 Banta, Emitt W., Saratoga, Wyo.
'05 Barbour, Prof. Thomas, Museum of Comparative Zoology, Cambridge, Mass.
'38 Barker, Elliott S., % State Game and Fish Commission, Santa Fe, N. Mex.
'37 Bass, John F., Jr., 23 East Jackson Blvd., Chicago, Ill.
'37 Baumann, A. C., State Fish Farm No. 4, Russell's Point, Ohio.
'33 Bauman, Albert J., State Fish Farm No. 4, Russell's Point, Ohio.
'33 Beach, U. Sidney, Highland, Mich.
'36 Beard, Daniel B., 72 Pondfield Rd. W., Bronxville, N. Y.
'37 Beckman, William, University Museums, Ann Arbor, Mich.
'37 Bedard, Avila, Deputy Minister of Lands and Forests, Quebec, P. Q., Canada.
'34 Bell, Edward B., 84 Foster St., Lowell, Mass.
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1939. Report on the disease of brook trout. Trans. Am. Fish. Soc., 1938, Vol. 68, pp. 450-461.

Note that the year of publication precedes the title and the year of the meeting is stated in the reference.

Please check your references carefully as to titles, spelling, capitalization, italics, diacritical marks, abbreviations, etc., against their original sources, after the final typing, and *state beneath your bibliography that you have done so.* Many biblio graphic titles published in the Transactions have been found to be incomplete and very inaccurate. Help us correct this situation.

11. **Tables.** Every table should have a heading. Number tables consecutively with Arabic, not Roman, numerals (1, 2, 3, etc.). Abbreviate the word "number" (No.) when referring to a special number—not when referring to quantity or things. Spell all other words in tables, including such words as "millimeters," "ounces," and "average," (except months *with date,* in body of table), and capitalize, as a rule, the first word only in headings in the first column or over other columns. Precede all decimal numbers with zero. Use dollar sign only with first number at top of column and under each cross rule. Note that no vertical lines are used to separate columns!

| Item | Number of fish | Percentage of total | Average length in millimeters | Months | Cost of diet per pound |
|---|---|---|---|---|---|
| Brook trout surviving experiment No. 2 | 23 | 5.8 | 6.5 | April-September | $0.05 |

12. **Capitals.** Capitalize words when used with a name or an identifying number or letter, or when referring to a particular State, Government, etc. For example: Lake Michigan, State of Michigan, or the State, the Province, the Republic, or the National and State Governments, Washtenaw County, Ann Arbor Township, Huron River, Pacific Ocean, North Atlantic, Northern States, Reservoir No. 1, Boulder Dam, Pond No. 1 or Pond A, State Fish Farm No. 1, Pisgah National Forest.

Capitalize names of sections of the United States, or of any other country as Middle West, but lower-case a term prefixed to any such sections, as eastern North Atlantic States.

Capitalize any term (except page or pages and age group) preceding Roman numerals, as Article I, Chapter II, Sample VI, etc. Also capitalize such terms as Appendix 1 or Appendix A, Experiment 2, Table 4, and Figure 8 (referring to illustrations).

Use lower case for scientific and common names of species. Capitalize scientific names of higher orders.

13. **Abbreviations.**

(a) Abbreviate the following:

*Clock time,* if connected with figures—2:30 a.m.

*Temperatures*—F. (Fahrenheit).

*Degrees,* whether referring to temperatures, longitude and latitude, or angles, etc.—75°, 75° F., 75° C.

*"Number,"* when preceding figures—No. 125; otherwise spell out.

*"United States,"* if preceding name of a department or a bureau or a vessel, etc.—U. S. Bureau of Fisheries, U. S. S. *Indiana.*

*Months,* in body of tables and footnotes to same when followed by day of month—Apr. 5-Sept. 2 (but April-September).

(b) Do not abbreviate the following:

*States, cities, etc.*

*Months,* in text or in headings of tables—April 5-September 2.

*Measures and weight, except p.p.m.*—6 inches, 20 millimeters, 5 ounces, 1.5 acres, etc.

*Percentage*—12 per cent, a percentage of 25.5.

14. **Numerals.** Spell out all *isolated* numbers which contain one or two digits, but use figures in a group of enumerations when any one number of that group contains more than two digits. Do not spell out numbers of three or more digits (except round numbers of approximations: "estimated at five hundred"), and always use a comma in a number of four or more digits. Treat alike all numbers in a series of connected groups. For example: There were fifty trout. There were 50 trout, 120 bass, and 5 pike. There were fifty trout, twenty bass, and five pike. There were 50 trout and 20 bass in one can, and 50 trout and 120 bass in the other.

Figures must also be used after a colon in text if matter runs on, irrespective of the number of digits, as: The following shipment was made: 24 trout, 50 bass, and 2 carp.

Use figures for all enumerations of dimension, weight, area, volume, distance (if fraction spell out, as one-half mile), clock time, money, percentage, degrees, proportion or ratios, age, dates, page numbers, decimals, and mixed numbers (spell out common fractions if alone: one-eighth). For example: $3.00 per 20 pounds; 5 feet 6 inches; about 10 miles; 6 acres; 15 cubic centimeters; 4:30 p.m.; fish died in one hour and twenty minutes at 30 minutes past 4 o'clock; 25.5 per cent; 75° F.; 1:10,000; trout 2 years 6 months old; 2-year-old trout; June 29, 1936; the 1st of January, 1938, the 20th day of March; 1937-38; 4.5 p.p.m.; 0.25; 1½ pages; page 215.

Write 8 by 12, not 8 x 12 unless multiplication is indicated.

Do not use two figures when two numbers appear together, as ten 12-room houses; twenty 6-inch trout.

Spell out figures beginning a sentence, but avoid such use of numerals if possible. Spell out both numbers of two related amounts at the beginning of a sentence in such expressions as "Twenty to twenty-five trout," but write "Two hundred fifty bass and 325 trout were shipped."

Spell out such expressions as the following: Between two and three hundred fish; there were thirty or forty thousand trout. Write 50-50, not "fifty-fifty."

15. **Use of hyphen.** Many compound words when used as nouns are not hyphenated but require use of the hyphen when used as adjectives. For example note the following sentences: "This was *cold water.*" "Trout are *cold-water*

fish.'' Write ''fish culture,'' but ''fish-culturist.'' Check your manuscript carefully for use of hyphen. The words, ''subspecies,'' ''upstream'' and many other words originally of compound derivation are written without a hyphen.

Write ''largemouth'' and ''smallmouth'' as one word when referring to black bass.

## III. SUBJECT MATTER

16. **Condense your paper** to the limit and omit all needless verbiage to reduce cost of printing. The manuscript should be simple, direct, clear, concise, accurate, consistent, and complete. *Accuracy* in subject matter, in scientific names, and in bibliography is especially important. Have your associates read and criticize your paper before the final typing. **Papers which are too poorly written will be rejected.** Do not expect your Editorial Committee to rewrite your manuscript.

17. **Be definite in references to species.** The scientific name, and wherever needed the complete common name, that will identify the species about which the paper is written should be included in the title as well as in the text, unless the number of species is too large. Such names as ''bass,'' ''trout,'' ''pike,'' and ''pickerel'' apply to any one of several species.

18. **Things to avoid.** The *words* "case," "instance," "show," "found," ''gave,'' and ''present'' are overworked in manuscripts, the same word sometimes appearing several times in one paragraph.

Avoid the repeated use of *participles* which, as a rule, weaken sentences. In the following illustration note the improvement when the words in parentheses are used: ''The principles underlying (that underlie) the production of beef are essentially the same as those involving (that are involved in) the production of bass.''

Avoid *split infinitives.* Please check your manuscript for this exceedingly common error.

Avoid the use of *this* and *these* as substantives. Compare, for example, the following two sentences for effectiveness: ''*This* was true in every *case.*'' ''*The mortality was high* in every *pond.*''

19. **Abstract of paper.** Give a condensed summary or brief abstract at the beginning of your paper, if at all possible. This abstract is especially desirable for all long papers.

*Prepared by Publications Committee, John Van Oosten, Chairman.*
*February, 1937 (revised 1939).*

## PART I. SUBJECT INDEX

## PART II. AUTHOR INDEX